CPE Comments and Topics

New look, same voice

This is the same voice: can thy soul know change?

THIS quotation from Browning's 'The Ring and the Book' summarises our feelings about the new design of the front cover and contents page. Elsewhere throughout the journal changes in type and presentation have been made, thus combining a fresh look with the consistently high standard of editorial material towards which we aim every month in CPE. Unlike the House of Dior, we are not obliged to come out with a controversial design every spring and autumn, but we do feel that a new suit of clothes once in a while is beneficial.

Our aim in CPE has always been to serve as a bridge between the academic and the industrial engineers. Unfortunately, an ever-widening gap seems to exist between these two groups; often neither is conscious of the requirements or outlook of the other. The history of chemical engineering, however, clearly indicates that advances in fundamental knowledge made by the academic research worker have been applied to serve practical purposes by the industrial engineer and, conversely, processes developed empirically in industrial plants have often been usefully studied by the research worker, with a net gain in further fundamental knowledge. As a rule we publish papers, articles and reviews which have been contributed by chemical and other engineers working both in industry, university laboratories and other research laboratories, so that the wide range of our readership can appraise the current state of knowledge throughout the chemical industry. As an example of this tendency we recently initiated two series of articles which are of particular importance to chemical engineers generally: 'Materials of Construction for Chemical Plant' and K. L. Butcher's re-examination of 'Chemical Engineering Fundamentals'. We are now planning further such series dealing with other fundamental topics.

Because we incorporate ATOMIC WORLD we take a special interest in the nuclear industry; it is our opinion that this industry has been built mainly by the efforts of chemical engineers. Indeed, it may be argued that the chemical engineering approach to nuclear technology is in a large measure responsible for the remarkable development of this young industry since the end of the second world war. Hence our articles on nuclear technology stress the chemical engineering principles underlying this industry.

Besides our articles, we have regular news features, book reviews by outstanding specialists and reports on congresses, symposia and exhibitions held all over the world which are of direct interest to those associated with the chemical industry. We feel sure that this combination of comprehensive articles, topical features and attractive presentation is agreeable to our readers. CPE now has a 'New Look' but the voice will continue with its same individuality as hitherto.

Economics and corrosion

THERE are two kinds of cost with regard to the economics of corrosion—the cost of doing something and the cost of doing nothing. One example of the former is the specifying of unnecessary costly alloys or unnecessarily thick metals as an insurance against corrosion; in other words, empirical remedies for a problem about which too little is known. The saving that can be achieved when more knowledge is acquired is shown by the example of a 225-mile 8-in. pipeline in which, because of proper protective measures being taken, it was possible to reduce the wall thickness and save 3,700 tons of steel. Dr. J. C. Hudson, recently retired head of the Corrosion Section of the British Iron and Steel Research Association, has calculated that the cost of protective processes applied to steel in the U.K. during the year 1957 was roughly £200 million. About half of this sum was spent on painting, and one-fifth on galvanising, *i.e.* painting £100 million, galvanising £35 million, tinning £10 million, and other processes £55 million.

The petroleum industry has been using organic film-forming inhibitors in process streams for several years. Due to their use, corrosion by sulphides, chlorides, organic acids, oxygen and other compounds in the presence of water, where alloy or other methods were not adequate or economical, has been controlled. In the U.S.A., refiners spend approximately $1/1,000 bbl. of crude oil charge or $3 million p.a. for these organic inhibitors.

The cost of cathodic protection plus coating of a pipeline is less than half the cost of repairing leaks caused by corrosion if protection is not provided. Cost of repairing leaks can amount to as much as from 2 to 5% of the cost of the pipeline, while cathodic protection can be provided for about 2% of the original investment. In a test involving 294,158 ft. of 3-in. distribution line, the Southern California Gas Co. found that repair costs dropped from $16,843 to $9,973 in the first year after cathodic protection had been applied. By the third year, pitting repair costs had declined to about $7,000. The cost of the corrosion control was estimated at $6,340 p.a. Thus, by the third year, the company had begun to reap a saving of over $3,000 p.a. on cathodic protection of the test sections of line.

The supervisor of engineering standards for the company, who gave these figures at a meeting this year of the American Society of Civil Engineers, estimated that in the U.S. corrosion of all types of pipelines takes a toll of over $1,000 million p.a.

Such stark figures show the vital importance of corrosion prevention throughout industry. The Corrosion and Metal Finishing Exhibition which will be held at Olympia from November 29 to December 2 will probably be the world's largest display of anti-corrosion and metal-finishing products and services.

Our special exhibition preview in this issue describes many products of particular interest to chemical plant engineers which will be exhibited at Olympia.

Industrial pollution

THE activities of alkali inspectors are of vast importance to the British chemical industry; yet how many people actively engaged in that industry realise this?—often inspectors are considered an unnecessary nuisance. The recently published Annual Report on Alkali, etc., Works by the Chief Inspectors, 1959, is a formidable booklet full of interesting facts. The inspectorate's task, in fact, is to ensure that air pollution from a great variety of industrial processes is reduced to a minimum. Until 1958 they were mainly concerned with the heavy chemical and allied industries—but as a sequel to the 1956 Clean Air Act the scope of the Alkali Act was greatly extended to include many other operations where control of smoke and grit presents special technical difficulties. The report states that during 1959 specific complaints concerning 354 works were investigated; this compared with 270 in 1958 and 133 in 1957. Complaints were found to be more numerous against gas and coke works (63), ceramic works (51), electric power stations (31) and iron- and steelworks (30). Furthermore, there were also 15 complaints against particular areas such as Thames-side (cement), Trafford Park (heavy industrial and chemical), Aldridge (blue brick) and three Pennine areas (limestone operations and lime burning).

There were more complaints against gas and coke works than any other class of works. Thus emissions from coke works employing horizontal retorts present an almost insoluble problem, but the report states that the use of this type of plant is declining. As far as power stations are concerned, the very small stations accounted for a 'disproportionate' amount of the considerable volume of complaints. It would seem that all these stations are, anyway, doomed as the C.E.G.B. is actively engaged in closing them. The medium power stations of about 60 MW have the most serious problem, since they still have a fairly long life before them and therefore are an appreciable potential nuisance. In some stations, for instance, emissions were found to be due to poor maintenance of arrestment plant resulting in its operating below maximum efficiency. Fortunately the problem of emission at the big new power stations of 1,000 MW and over were largely solved at the design stage. The problem of emissions at iron- and steelworks is also being tackled and it can only be overcome by a proper selection of fume control plant—these were thoroughly surveyed by Dr. W. E. Strauss in the August issue of this journal.

Carbon tetrachloride

A PARADOX has developed in the U.S. chemical industry which will probably lead to a substantial increase in the construction of carbon tetrachloride manufacturing plants, despite the fact that present production capacity exceeds demand. It was recently predicted that construction of the new carbon tetrachloride plants should begin in the near future and continue for five to ten years, because the demand for lower chlorinated methanes, such as methylene chloride and chloroform, is increasing rapidly. The most economical method for producing these chemicals is by the direct chlorination of methane; about 35 to 40% of the carbon tetrachloride now consumed is produced by the chlorination of methane, with the balance produced by the chlorination of carbon disulphide. Carbon tetrachloride is a basic raw material in the manufacture of chlorofluoromethanes, which are widely used as refrigerants and propellants in aerosol containers. Both applications of chlorofluoromethanes are steadily growing, with aerosol containers being used for an ever-increasing number of products. About 65% of the carbon tetrachloride production is consumed in the manufacture of chlorofluorohydrocarbons, with the remainder used for such essential applications as solvents in industrial cleaning, grain fumigation and fire extinguishing. The U.S. chemical industry forecasts that the present 350 million lb. annual production rate for carbon tetrachloride should reach 500 million lb. by 1970.

Progress in DRAGON project

THE DRAGON reactor project recently completed its first year of operation, and the first annual report describes numerous activities undertaken by the O.E.E.C. team in the development, design and construction of the 20-MW high-temperature, gas-cooled reactor at Winfrith. The staff at Winfrith comprises 55 overseas members, 74 scientists and engineers seconded by U.K.A.E.A. and 59 ancillary and junior staff also seconded by U.K.A.E.A. It must be borne in mind that the U.K.A.E.A. has contributed the largest percentage (43.4%) to the total expenditure which is expected to be £13.6 million over five years.

In view of the fact that the coolant in the reactor is helium at 20 atm. pressure (inlet temperature is 350°C. and outlet temperature 750°C.) the heat-transfer problems associated with the reactor are quite fundamental. The programme of the heat-transfer group consists of numerous experiments designed to establish basic data for design calculations. This work can be divided into two groups: first, the gas dynamics group concerned with convective heat-transfer research and, second, the general physics and technology group covering research into other forms of heat transfer and technological development work associated with the programme. Much work has been carried out on forced convection heat transfer from surfaces whose temperatures differed little from that of the fluid passing over them. Less attention, however, has been given to

conditions where fluid and surface temperature differ considerably, as in the DRAGON reactor, for which insufficient reliable heat-transfer data are available.

In the design of the actual reactor the total thermal emissivity of several materials such as reactor graphite, nimonic alloys, stainless steel and uranium carbide is required. Since these materials have no published value of any certainty, the thermal emissivity was measured by using an optical method which consists of heating the material in tubular form and alternately observing the radiation emitted by a small hole in the tube wall and from the surface. The emissivity of the hole can be made very nearly equal to unity by selecting a suitable ratio of hole to tube diameter, so that by using an optical pyrometer the true temperature is given and comparing this with the surface temperature the spectral emissivity was obtained. A similar comparison using a thermocouple which measures the total radiation, *i.e.* radiation of all wavelengths, gave the total emissivity.

Chemicals' production review

THREE working parties of the O.E.E.C. Chemical Products Committee, dealing with dyestuffs, petroleum chemicals and plastic materials respectively, met in Paris recently to discuss the present situation and prospects in their sectors of the industry. The dyestuffs working party met under the chairmanship of Mr. F. Brichet, of Switzerland, to discuss the dyestuffs situation in 1959 and prospects for the current year. It was noted that Western European dyestuffs production increased by 21% last year to reach the record figure of 128,000 tons—trade rose even more rapidly, especially trade between the European countries themselves. The working party expects demand to remain strong on both home and export markets in 1960, and the high level of output of 1959 to be maintained or even slightly surpassed.

The petroleum chemicals working party met to review petroleum chemical production in member countries in 1959 and plans for expansion up to the end of 1962. O.E.E.C. countries invested $270 million in this sector in 1959, compared with $226 million in 1959. In 1960 to 1962 more than $800 million are expected to be invested.

The plastic materials working party, under the chairmanship of Mr. W. Mauss, of Germany, met to review sales of plastic materials in member countries in 1959, trade in plastic materials and future trends in production. Total sales of plastic materials by O.E.E.C. countries amounted to slightly more than 2 million tons in 1959, an increase of 24% over sales in 1958. For the same time United States sales rose by 21% to reach 2.3 million tons. As in previous years, the most rapid expansion has taken place in the thermoplastics field, where sales rose by 32% in 1959, compared with 19% in 1958. There were also considerable investments in 1959 in plant for the manufacture of thermoplastic materials. It is noteworthy that Germany's estimated *per capita* consumption of plastic materials in 1959 (12.2 kg. per head) exceeded that of the United States (11.1 kg.) and the U.K. (7.5 kg.).

Petrochemicals in Australia

THE most flourishing branch of the chemical industry in every country during the last few years has been petrochemicals. It is interesting to watch how one country after another is entering the 'petrochemicals race'; thus in Australia, since the end of the war, a large-scale refining industry has been established which is now able to satisfy virtually all national oil requirements. As a natural concomitant of oil refining a total of about £40 million has been earmarked for the petrochemicals industry; this includes both expenditure on plants at present in operation as well as provision for plants to be erected in the near future.

The largest project, involving an investment of £20 million, is associated with the Altona refinery near Melbourne. One of the most important raw materials to be produced at Altona will be styrene monomer, which will eventually be made available not only to processing plants erected in the neighbourhood but to manufacturers all over the country who require it for manufacture of polystyrene, styrene-based plastic paints and resins for fibre-glass mouldings as well as numerous other products. It is also planned that by 1965 the plant at Altona should produce 30,000 tons of general-purpose rubber (SBR). Polyethylene and a range of vinyl plastics are among other products to be manufactured in the area.

A somewhat smaller range of products will be produced at Clyde near Sydney. There, a joint undertaking involving both oil and chemical companies is planning the production of ethylene and epoxy resins. At Geelong, near Melbourne, a plant to manufacture detergent alkylate is almost near completion. These important petrochemical developments planned for Australia suffice to show the scope and initiative in a country so far removed from the industrial centres of U.S.A. and Europe.

Chromatography for quality control

THE benefits to be gained by applying the correct instrumentation in process control are discussed in this month's special feature. Some economic savings obtained by using quality controllers were recently described by Dr. D. J. Fraade at a symposium on quality control organised by Elliott Bros. (London) Ltd.

Details of two successful applications of closed-loop process control, based upon stream analysis and involving continuous process chromatography and continuous p.p.m. detection of moisture were given. The initial objection to using the continuous process chromatography was that it gave a batch-type analysis resulting in a non-continuous indication of the key component concentration. The analysis time, in the then existing analysers, was of the order of 10 to 20 min. for C_4s. For applications involving only monitoring, these times were adequate, but for a closed-loop approach the key component appearance was, in some cases, too infrequent to allow proper action to be taken in the event of an upset. These drawbacks have now been obviated with the development of high-speed chroma-

tography where analysis cycles are in the order of 1 min. or less for components through the C_5 range. The need for key component peak storage between analyses has also been met by commercially available memory devices suitable for either pneumatic or electronic control instrumentation.

Dr. Fraade described one of the most universal applications which has been in natural gasoline plants, at the Reef Corporation, Texas. This company purchased a process chromatograph and a pneumatic control system; the analyser samples the bottom product of the de-ethaniser for ethane as an impurity, and controls the ethane content to a feasible and allowable maximum so that the overhead propane product from the downstream depropaniser meets the vapour pressure specification for L.P.G. With this type of plant, revenue is gained by the sale of the liquefied natural gas products from the gas in the oil wells. The uncondensed portion of the gas is also sold, but the ethane content is here worth only 0.39 cent/gal. as against 40 cents/gal. when sold as a propane product. The increase of 2% in the ethane content of the propane product achieved was sufficient to recover the cost of the control system in six months.

Eurochemic fuel-processing plant

THE European Nuclear Energy Agency, part of the Organisation for European Economic Co-operation (O.E.E.C.) formed a company last year for the chemical processing of irradiated fuel. This company, Eurochemic, recently inaugurated work on a pilot fuel reprocessing plant at Mol, Belgium. Designed to have quite a versatile performance, the plant should process uranium or uranium oxide fuels of up to 5% U^{235} enrichment.

It will operate as follows: The fuel elements will be shipped to Mol from the reactor site in heavily shielded casks. When they arrive they will be transferred to deep, water-filled storage ponds which can accommodate all types of fuel. From the storage pond the fuel elements are transported and dropped by remote control into the dissolution cells, where the canning material is dissolved with a special solution. This solution is removed and sent to 'hot waste storage'. The fuel itself is subsequently dissolved in nitric acid, which forms radioactive gaseous products further treated in a specially equipped cell. At the end of this operation a solution containing all the uranium, plutonium and fission products in the form of nitrates remains behind. This solution is pumped to the extraction section where it is contacted with the organic extracting agent. Contact takes place in pulsating columns filled with perforated plates where mixing is accomplished by pulsating the liquors in the columns. The fission products are isolated in the extraction cells and the U and Pu are obtained in separated portions in the nitric acid. Since the U portion still contains some radioactive fission products it is further purified by passing through a column of silica gel. The procedure for final purification of Pu has not yet been finally developed—this is one of the main objects of the pilot plant.

The organic extracting agent is partly decomposed during the process and will be continuously regenerated in the solvent recovery system before it is again used. The nitric acid solution leaving the first extraction column contains the bulk of the fission products but less than 0.2% Pu and U. This effluent is concentrated to a small volume which is then stored in tanks. Distillate from the fission product concentrator and other acid effluents from different parts of the plant are too active to be released, they are therefore concentrated in the acid recovery system and then recycled into the dissolver vessel. Other active effluents from the entire site are concentrated as 'hot waste' which is subsequently stored in steel tanks.

Acetal resin plant

A NEW plant for producing *Delrin* acetal resin is to be constructed by Du Pont de Nemours (Nederland) N.V. on its plant site in Dordrecht; production operations are scheduled to begin in 1962. This plant will include facilities for extrusion, cutting, packaging and shipping of *Delrin* acetal resin.

Delrin is a highly crystalline, high-melting thermoplastic polymer, known chemically as a linear acetal resin or as polyoxymethylene. Its dense crystalline structure accounts for many of its properties—strength and stiffness, high-temperature behaviour and solvent resistance. It is one of the first plastic materials with strength properties approaching those of the non-ferrous metals. Although the plastic is heavy by comparison with most other plastics, it is lighter than any of the die-casting alloys: 80% lighter than zinc, 45% lighter than aluminium and over 20% lighter than magnesium. One of its applications has been in the manufacture of pump bodies and impellers and possibly many other types of chemical plant.

There is no substitute for beer

ONE would have thought that this statement was self-evident to everybody. Nevertheless, we were informed recently that an exhibitor at the Brewers' and Allied Trades' Exhibition, who was demonstrating the use of glass pipelines in breweries, was circulating gravy browning through the pipeline. The reason for this was that the use of beer would have involved excise complications.

According to the sales director of the exhibitor's company, gravy browning is the best substitute for beer. This had been brought home to them by bitter experience, because at another exhibition in Copenhagen the same company tried to simulate whisky by using cold tea. The external appearance of cold tea in glass was so whisky-like that the Danish revenue men insisted on opening the still to taste the whisky. As the tea had been stewing for a week their remarks upon tasting were far from complimentary.

We now wonder whether the British Excise authorities will be similarly tempted to taste the gravy browning—perhaps they may like what they taste and as a result gravy cubes might soon be on sale in all reputable off-licence establishments.

Application of Process Dynamics to Process Control

By W. D. Armstrong,* M.A., Ph.D., A.M.I.Chem.E., A.M.I.Mech.E.

The advisability of examining the performance of a plant under dynamic conditions has become more marked with the increasing importance of automatic process control. In this article, the author describes the application of process dynamics to process control. Fundamental data required for analysis of control loops are discussed and the control characteristics of a stirred tank liquid heater and a simple distillation column are fully described, thus illustrating the importance of a knowledge of the dynamic characteristics of chemical plant.

FOR many years the conventional approach to process plant design has been based on the steady-state characteristics of the plant. With the growing importance of automatic process control, the design must take into account the performance of the plant under changing or dynamic conditions since it is these characteristics which determine plant controllability.

Basically most simple control systems for continuous processes may be considered in general terms as a block diagram (Fig. 1). One block represents

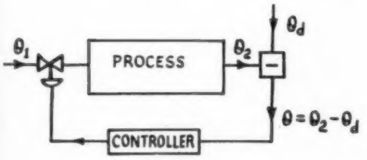

Fig. 1.

the process with, as its input, the process stream by variation of which control is achieved (θ_1). The output of the process block is the flow quantity or quality which is being controlled. This controlled quantity or quality must be measured (θ_2) and then compared with its 'desired value' (θ_d)—the value which the control system is attempting to maintain. It is the difference between the measured value and the desired value of the controlled condition, the deviation θ, which forms the input to the controller. The controller then provides a corrective action which is dependent on the magnitude and form of the deviation as a function of time. The

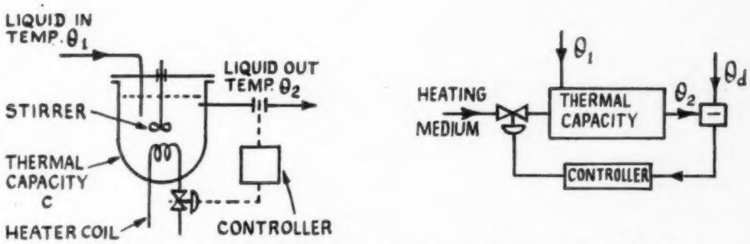

Fig. 2. Stirred tank liquid heater together with corresponding equivalent block diagram.

fundamental data required for a theoretical analysis of the control loop are:

(*a*) the dynamic characteristics of the process and measuring unit; being the relations
  - (i) between the disturbance and the controlled or measured variable
  - (ii) between the corrective action and the controlled variable;

(*b*) the dynamic performance of the controller.

The performance of the controller is usually known or can conveniently be determined, but the dynamic characteristics of the process may be more complex. First a simple example will be considered. In Fig. 2 is shown a stirred tank liquid heater together with the corresponding equivalent block diagram. The controller is required to maintain the liquid outlet temperature constant at some predetermined value θ_d and does so by measuring that temperature and controlling the flow of heating medium. Disturbances may arise in either the flow or temperature of the incoming liquid or in the heating medium. If we consider a disturbance in the inlet temperature, then the 'process dynamic characteristics', *i.e.*

- (i) the relation between the temperatures θ_1 and θ_2 with constant heat supply and
- (ii) the variation of outlet temperature as the heat supply is changed with constant inlet temperature,

may be directly derived from a heat balance on the plant expressed as a function of time.

The heat balance may be written

$$QC_p\theta_1 + QC_p(\theta_d - \theta_{1s}) - C(D)[\theta_2 - \theta_d] = QC_p\theta_2 + c\frac{d\theta_2}{dt}$$

where Q is the liquid mass flow rate,
C_p is the liquid specific heat,
c is the thermal capacity of the vessel and its contents (thermal capacity of heating coils assumed negligible),
θ_{1s} is the steady-state value of θ_1 corresponding to desired

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value of the outlet temperature θ_d with no corrective control action, and

$-C(D)$ is the differential operator function representing the controller (when operating on the deviation it gives the corrective heat supply).

Writing

$$R = \frac{1}{QC_p}$$

and noting that θ_1 and θ_2 are functions of time

$$[RcD + 1 + RC(D)]\theta_2$$
$$= [1 + RC(D)]\theta_d + \theta_1 - \theta_{1s}$$

This equation enables θ_2 to be calculated as a function of time for any specified variation of the inlet temperature θ_1 if the controller characteristic $C(D)$ is known.

Distillation column control

The control of a distillation column may be taken as an example of a more complex process. In a continuously operating fractional distillation unit, the aim of the control system is to maintain a predetermined state of equilibrium, notwithstanding any disturbances which may occur in the flow, composition or enthalpy of the material streams entering or leaving the plant, or in the heat flows to the reboiler or condenser. In binary distillation in a plate-type tower the process variables to be controlled may be considered as (*a*) concentration, temperature and pressure distribution in the column, (*b*) rate of flow of top and bottom products, and (*c*) liquid levels in reboiler or condenser units. The control could provide corrective action using (*a*) reflux flow rate, (*b*) heat flows to reboiler or condenser, and (*c*) feed or product flow rates.

Many combinations of the controlled variable and the corrective action are possible, but one simple loop will be considered—the maintenance of a constant top product composition by variation of the reflux flow rate. This control system is shown in Fig. 3a. It is usually impracticable to measure the top product composition directly and some indirect measurement of the equilibrium of the column has to be made. This is often the temperature profile in the column, indicated diagrammatically in Fig. 3b. The temperature at any point only gives an indirect indication of the composition if the pressure is maintained constant, but assuming that this may be done, variations in the profile can be detected by measuring the temperature at a single point. The actual point chosen for measurement depends primarily on the variation of the profile with changes in the product compositions and, as will be seen later, the choice is important.

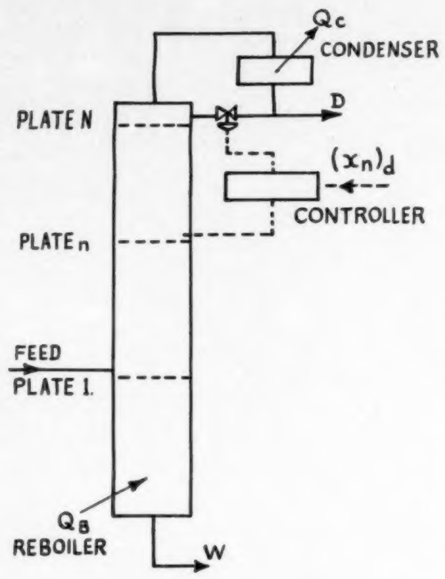

Fig. 3a.

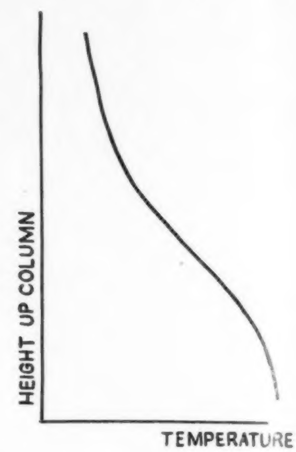

Fig. 3b.

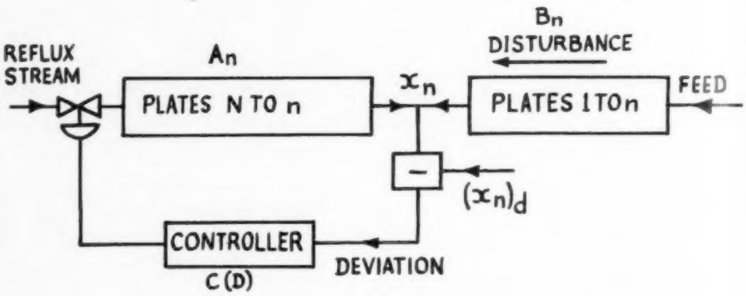

Fig. 4.

Fig. 4 shows the simplified block diagram which represents this particular control loop. In the following discussion only one disturbance will be considered. If the flow of heating and cooling media are maintained constant, disturbances are most likely to arise in the feed flow, composition and enthalpy. The diagram shows the effects of a disturbance in feed composition.

It is assumed in the simplified diagram that there is no interaction between the transfer functions A_n, connecting change of composition on plate *n* with reflux flow rate, and B_n, connecting change of plate composition with change of feed composition. B_n, for instance, is dependent on the reflux ratio and the control action will therefore result in changes in B_n, but in this simplified diagram this effect is regarded as secondary.

Using the transfer functions (functions of the differential operator $D = d/dt$) as defined below, the overall loop transfer function $F(D)$ may be obtained as follows.

Loop transfer function

If at any time t, x_n is the fraction of the more volatile component on plate *n* and $(x_n)_d$ the value required on that plate to provide the desired composition of top product, then the deviation θ, *i.e.* the input to the controller, is

$$\theta = \delta x_n = x_n - (x_n)_d$$

—a function of time.

Since the transfer function for a series of separate units is the product of the individual transfer functions, the corresponding change in reflux flow rate is

$$-V(D)\ C(D)\ \delta x_n$$

where $V(D)$ is the operator representing the effect of the regulating valve and $C(D)$ the operator representing the controller.

The corresponding change in plate composition x_n is therefore $-A_n(D)\ V(D)\ C(D)\ \delta x_n$, but to this should be added the change due to the disturbance δx_F, *i.e.* $B_n\ (D)\ \delta x_F$, then

$$\delta x_n = B_n(D)\delta x_F - A_n(D)\ V(D)C(D)\ \delta x_n$$

i.e.

$$F(D) = \frac{\delta x_n}{\delta x_F} = \frac{B_n(D)}{1\ +\ A_n(D)V(D)C(D)}$$

It should be noted that this equation does not relate changes in top product composition to feed changes, but gives composition changes on plate n which was specified as the controlled quantity which could be taken to represent the equilibrium of the column. This equation for $F(D)$ is the fundamental system equation for the distillation column plus its control system. The form which the overall response takes is determined by the roots of the characteristic equation

$$A_n(D)V(D)C(D)\ +1\ =\ 0$$

For example, it is this equation which determines the approach of the control system to instability.

It may now be seen that, in order to determine δx_n for a specified δx_F, a knowledge is required of each of the transfer functions. Assuming that $V(D)$ is known or may easily be determined and that $C(D)$ may be specified $A_n(D)$ and $B_n(D)$ remain. These are respectively the dynamic relations between composition on plate n and reflux flow rate and composition on plate n and feed composition. A theoretical approach to the derivation of A_n and B_n requires the solution of the equations which govern the time behaviour of the system. For many types of plant (*e.g.* tanks, buffer vessels and some types of heat exchanger) these equations are relatively simple, but for the distillation column and similar types of complex units the full equations are usually non-linear and too complex to provide convenient expressions for A_n and B_n.

There are several approaches to the problem, including:

(*a*) Numerical solution of the full or modified equations using a digital computer.[1]

(*b*) Analytical solution of approximate linearised equations with parallel experimental tests to check the validity of the approximations.[2]

(*c*) Experiments on a column measuring the output response corresponding to an input disturbance in the form of a pulse, step, ramp or sinusoidal signal.[3] Alternatively, methods are available which enable a dynamic analysis to be made from a statistical examination of normal random variations in the variables during the operation of the system.

(*d*) Construction of an analogue, usually electrical in form; experiments may then more conveniently be performed on the analogue.[4]

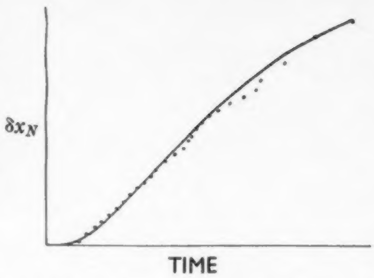

Fig. 5. Response of the top product to a step change in feed composition.[5]

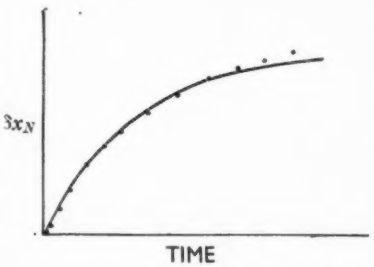

Fig. 6. Response of the top product composition to a step change in reflux flow rate.[5]

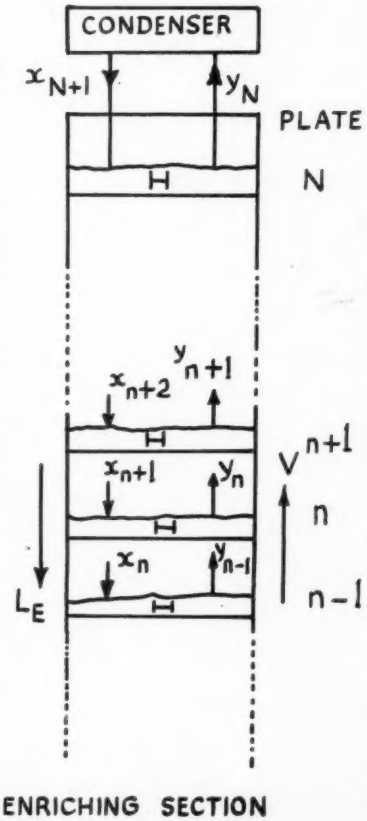

Fig. 7.

The disadvantage of (*a*), (*c*) and (*d*) is that in a system where there are a large number of variables many tests or solutions have to be obtained, since each test or solution corresponds to only one combination of variables. There are certainly equivalent disadvantages in (*b*) since, in order to obtain relatively simple expressions for the transfer functions, there must be considerable simplification of the equations. Examples of the application of each of these methods to a distillation column are given in the references quoted.

Analytical solution

The author has been particularly concerned with attempts to obtain analytical solutions for the distillation column. In Fig. 5 a comparison is shown between the approximate theoretical response and the experimentally measured response of the composition on the top plate following a step change in feed composition (transfer function B_n). The corresponding response arising from an imposed step change in reflux flow rate (transfer function A_n) is shown in Fig. 6. The experiments were in this case carried out on a 21-plate 4-in.-diam. laboratory column using benzene-carbon tetrachloride as the binary system. The composition on each plate was determined either by withdrawing a liquid sample and making refractive index measurements or, when the experiment was continued until the new equilibrium state was reached, a sample taken off the plate was pumped through a continuously read microhydrometer and then returned to the plate.

The corresponding theoretical analysis is based essentially on a material balance round a typical plate (n). For example, for the enriching section shown in Fig. 7, the basic assumptions made are that:

(1) Plate efficiency, which can be measured experimentally, is independent of time and is constant for all plates.
(2) The liquid holdup H on the plates is perfectly mixed and is independent of the liquid flow rate.
(3) The vapour holdup is negligible.
(4) The column operates adiabatically.
(5) The pressure is constant throughout the column.
(6) The time to attain fluid dynamic equilibrium is small compared with the time for mass transfer.
(7) The feed enters the column as saturated liquid.
(8) The binary mixture being distilled has constant molal volume and latent heat and its vapour-liquid equilibrium relationship can be represented by two straight lines.

Then a material balance for the more volatile component for plate n in the unsteady state, with step change in the reflux rate ΔL_E imposed at time $t = 0$, gives

$$(L_E + \Delta L_E)(x_{n+1} + \delta x_{n+1} - x_n - \delta x_n) + V(y_{n-1} + \delta y_{n-1} - y_n - \delta y_n) = \frac{\partial}{\partial t} H(x_n + \delta x_n)$$

where L_E is the molar reflux flow rate
V is the molar vapour flow rate
H is the molar plate holdup
x_n is the mole fraction of the more volatile component in the liquid on plate n at time $t = 0$
y_n is the mole fraction of the mole volatile component in the vapour leaving plate n at time $t = 0$.

(The column and experiments are fully described in Ref. 3 and the analytical treatment is given in detail in Ref. 5.)

From approximate solutions of equations of this form, using the appropriate end boundary conditions it is possible to derive expressions for $A_n(D)$ and $B_n(D)$. The experiments, apart from checking the general validity of the assumptions made, may be used to show the importance of some secondary variables on the dynamic response, *e.g.* the change of plate holdup with liquid flow rate or heat-transfer effects.

Further work is proceeding on the interaction between changes in reflux flow rate and feed composition changes since in a practical system these changes will, of course, occur simultaneously. One of the author's colleagues is also extending the experimental work to tests on a full-scale distillation column. This is a necessary step before any practical application is possible.

When convenient expressions have been derived, either analytically or empirically, for the functions $A_n(D)$ and $B_n(D)$, consideration can be given to the form to be specified for $V(D)$ and $C(D)$, the regulating unit and controller characteristics. In general, therefore, it is necessary in a particular example to find a method of expressing the desired response function of the controlled quality for whatever disturbance may arise. This may be straightforward with a simple process loop, but in most cases the choice of criteria may be dependent on, for example, the particular distillation. Examples of possible criteria are the minimum size of

$$\int_0^\infty \delta x_N dt$$

or the minimum value of the largest overshoot occurring in δx_N. Much research is still to be done in the development of suitable criteria and in most cases economic considerations will be very important.

It will be seen that in the case of the distillation column it is also possible to modify the size of the control loop, since with temperature measurement at a higher point in the column the effective $A_n(D)$ will be reduced, though it should be noted that for feed composition disturbances the effective $B_n(D)$ will be greater. The optimum position for the measuring unit cannot yet be determined for the general case. It is usually found by trial and error. If more than one disturbance is likely to arise in the same control loop than a compromise between the two separate control requirements must be devised.

More complex control systems

In the example considered only one process control loop has been discussed; in practice, however, more than one loop is often necessary, *e.g.* in the distillation column a controller is required to regulate the reboiler heat supply. The control loops usually interact on one another and cannot be considered independently, and then the analytical treatment of the final loop equations becomes even more complex. However, it is possible that the development of optimising control systems may change the picture. In these control systems the controller might make small changes in the various flows in a predetermined order, and after each change measure the result, compute the overall quality or efficiency and so determine which change and what size of change to make permanently.

It seems probable that this system of control, when applied to a chemical process, such as a distillation unit, can best be used in conjunction with an analogue computer. The experimental determination of the optimum changes to be made would then be carried out on the analogue and not the plant, since by this means the time scale could be considerably speeded up and the time for each trial change made very small. Before this is possible, realistic approximate expressions for the dynamic characteristics must be devised in order that a relatively simple analogue can be used.

The importance of a knowledge of the dynamic characteristics of chemical plant will continue to grow as more processes are designed to operate with full automatic control as an integral feature.

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Further 'Courtelle' expansion

Courtaulds Ltd. have decided on a further large increase in capacity for their acrylic fibre *Courtelle*. This will bring total U.K. capacity up to 32 million lb. p.a. The capacity of the *Courtelle* plant in France, due to start operating next year, will be 10 million lb. p.a.

The initial commercial production of *Courtelle* began at Coventry in 1957, where existing annual capacity is 2 million lb. This was followed by the construction of a 10-million-lb. plant, which started production early in 1959 on the company's 500-acre industrial site at Grimsby. In the same year it was decided to build a second 10-million-lb. plant at Grimsby which is due to start shortly. The latest decision involves a third 10-million-lb. plant at Grimsby on which preparatory work has already reached an advanced stage.

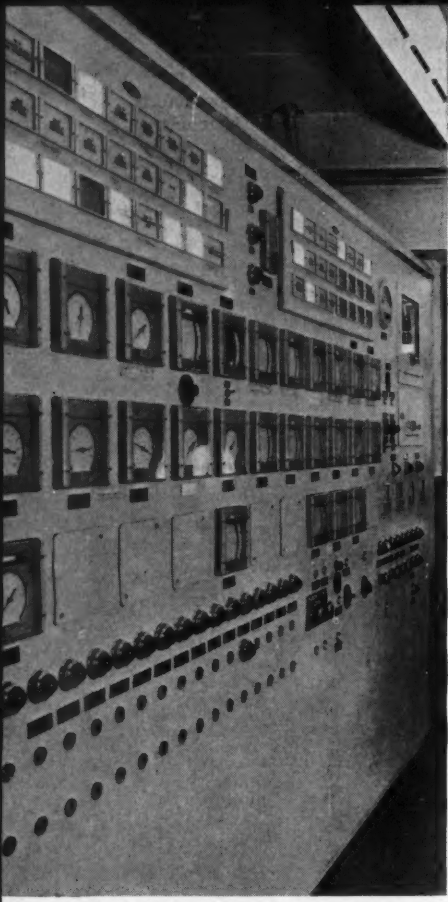

Fig. 1. Main control and instrumentation panel.

Instrumentation of a Pilot Plant

By S. Brodnicki,* Dipl.Ing.

Since the real product of a pilot plant is not what comes out at the end but the information collected from the various sections, instrumentation of such a plant poses many unique design problems. This article describes some problems associated with the instrumentation of a pilot plant for a pressurised slagging coal gasifier, involving a process for the conversion of low-grade coal into gas.

THE instrumentation of a pilot plant poses a set of design problems which are different to those applying to a full-scale plant. This can be appreciated if it is remembered that the real product of a pilot plant is not what comes out at the end of the process but information which is collected from the various sections of the plant. It will not be surprising, therefore, to find a pilot plant heavily equipped with measuring, recording and controlling devices, many of which would not be justified by normal design economics.

The principles which should govern the design of the instrumentation and control system for a pilot plant are as follows.

(1) The system should provide efficient means of controlling the operation of the plant.

(2) The design should provide the means of proving the efficiency of measurement and control systems proposed for the full-scale plant.

(3) The system should provide adequate and efficient means for the collection of process and plant data in a form suitable for further study or processing.

(4) The system should safeguard the safety of the plant and of the operating personnel.

(5) The system and its installation should be flexible and should lend itself to easy changes and modifications.

The instrumentation system on the pilot plant described in this article was designed with these factors in mind. This particular example is also interesting as it illustrates the use of an unusually wide variety of instrumentation techniques including more special ones like automatic fuel handling, gamma-ray level detection, gas analysis, automatic weighing, data logging and the use of closed-circuit television.

Pilot plant

The pilot plant which is represented on the flowsheet (Fig. 2) is a pressurised slagging coal gasifier. The process was conceived for the purpose of converting low-grade coal into gas suitable for town gas or chemical synthesis processes. The fact that the gas would be generated at a high pressure offers considerable economic advantages.

The process is based on a reaction between coal, oxygen and steam in a bed of coal. Above a free slagging temperature (about 1,500°C.) gasification reactions in the presence of an excess of carbon go rapidly towards equilibrium, leaving little of undecomposed steam and CO_2. The gas rises in countercurrent with the descending solid fuel, thus leaving much of its sensible heat to support the reaction. The process as originally designed included the injection of pulverised fuel together with oxygen and steam entering the hearth. Up-to-date experiments have not reached the stage of commissioning the P.F. system, which has therefore been omitted from the present discussion.

It should be noted that the article describes an early version of the plant. Various modifications and improvements have been introduced since the plant has last been in operation.

The design of the pilot plant was based on a maximum throughput of 2.5 tons/hr. of solid fuel with 1.7 tons/hr. of oxygen and 0.95 tons/hr. of steam, producing 200,000 S.C.F.H. of gas, but the plant was only operated

* *Constructors John Brown Ltd.*

at throughputs of up to 1.7 tons/hr. of fuel and it produced up to 140,000 S.C.F.H. of gas. The typical composition of the gas was 73% CO, 24% H_2, 1.4% N_2, 0.9% CO_2, 0.26% O_2, 0.32% H_2S and 0.05% CH_4.

In the initial experimental phase coke was used instead of coal. Oxygen was obtained through the evaporation of liquid oxygen and steam was provided from a small packaged boiler. The gas which was generated during experimental runs was burned in a stack and slag was discharged in the form of frit produced by quenching molten slag in water. In order to ensure a free and continuous flow of slag from the hearth of the gasifier, 20% blast furnace slag was mixed with the coke which was fed to the gasifier.

Coke and blast furnace slag were drawn from bunkers and fed to the gasifier through constant weight feeders, conveyor belt, skip hoist and a lock hopper system. The oxygen and steam mixture was fed to the gasifier through a horizontal tuyere located above a tap hole through which molten slag flowed into a pool of water. When dropping into the water the slag disintegrated and formed small-sized frit. The appearance of the frit was similar to that of coarse sand and the material could be discharged as a suspension in water through the bottom of the gasifier shell. Make gas was passed through a venturi scrubber and a hydrocyclone, after which its pressure was let down before feeding it to the combustion chamber at the bottom of the stack.

The hearth of the gasifier was cooled by a single water-tube boiler rated at 600 p.s.i. The steam which was produced could be superheated and used in the process or alternatively vented to atmosphere. A system of water pumps was provided to ensure a circulation of water through the bottom of the quench chamber and to return the water which was discharged with the slag. A supply of nitrogen was available from a liquid nitrogen evaporator. Nitrogen was used to purge the slag quench chamber so as to prevent the risk of accidents which would result from the accumulation of explosive gas mixtures. Nitrogen was also used for the purging of sight glasses mounted in the walls of the quench chamber.

Instrumentation

The plant was equipped with a comprehensive system of instrumentation for the collection of measurements and for automatic control. The design included a data logger for the purpose of presenting all the measurements digitally in tabular form and also on a punched tape for further processing by means of a digital computer. It was decided to make full use of modern electronic methods for the transmission of measurements and for automatic control. This fitted logically with the data logging system and provided an opportunity for the study of the characteristics and merits of electronic instrumentation as compared with the more conventional pneumatic systems.

The control room was designed so as to facilitate the task of the operator and to present him with all the necessary information in a way which would enable him to follow the performance of the plant and the state of the process. The control room was equipped

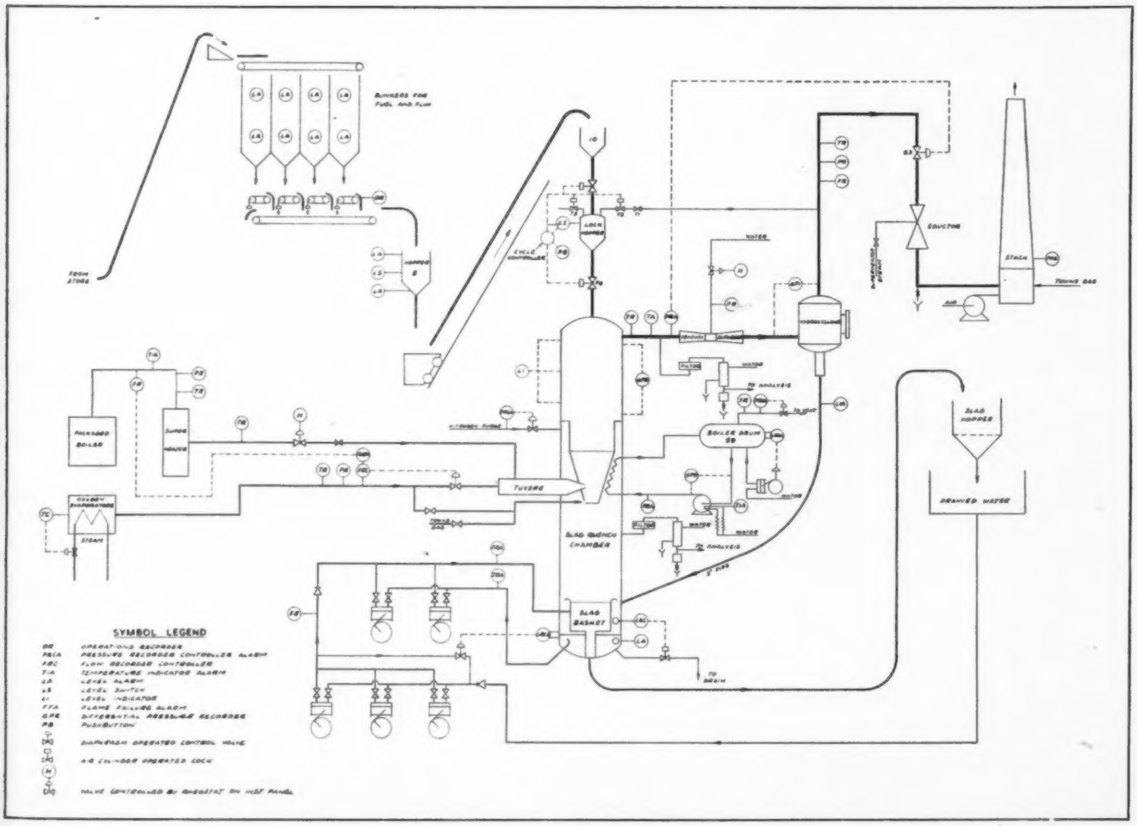

Fig. 2. Pressurised slagging gasifier flowsheet.

with a main instrumentation and control panel, an auxiliary instrument panel and a manual control desk. The main control panel contained recorders and indicators showing all quantities which were required for the operation of the plant. All automatic controllers and remote hand controls and switches were also mounted on this panel. The main control panel is illustrated in Fig. 1, and it will be seen that it included an extensive annunciator system for the display of all warnings and alarm signals.

The auxiliary instrument panel carried multi-point potentiometric recorders measuring variables which were not of immediate and continuous interest to the operator. The manual control desk contained the operating handles of the most important valves and control switches for some of the electric drives. A subsidiary local panel was mounted in the solid fuel handling bay on which certain warning signals and controls were duplicated for the benefit of the man in charge of that section of the plant.

Automatic control of the plant

(a) Solid fuel handling

The flow of solid fuel to the gasifier was controlled by the rate of operation of the skip hoist. The sequence of events leading to the introduction of a batch to the gasifier was controlled automatically by a cycle controller. The cycle of operations for the system was as follows.

The skip filled automatically when it reached the bottom of its travel. Upon receiving a signal from the cycle controller it rose, dumped the contents into hopper No. 10 and returned to the bottom. The cycle controller then passed the charge to the lock hopper by opening valve F.3. At the next step valve F.3 closed and the skip could start its next operation. Meanwhile, valve T.2 opened and allowed the purge gas to pressurise the lock hopper. After a suitable interval, valve T.2 closed and F.4 opened dropping the contents into the gasifier. At the last step the controller closed valve F.4 and opened valve T.3, thus de-pressurising the lock hopper. All the operations as described above were initiated by cam-operated switches. The cams were mounted on a common shaft. One complete revolution of the shaft corresponded with a complete sequence of operations leading to the introduction of one skip-load of fuel into the gasifier. Such a complete sequence of operations could be initiated by a push-button mounted on the main control panel.

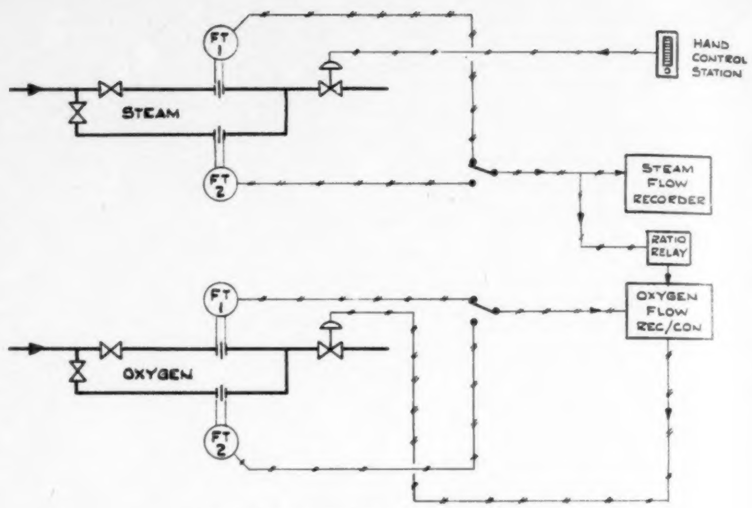

Fig. 3. Steam/oxygen flow ratio control system.

The total quantity of fuel fed to the gasifier over a period of time was measured by the total time of operation of the constant weight feeders which worked under the control of a level switch in hopper No. 8 to maintain a supply for the skip. The time of operation of each constant weight feeder and the total number of lock hopper cycles were recorded by a multipen operation recorder, thus giving a measure of total fuel throughput.

As the operator had to control the supply of solid fuel to the gasifier it was necessary to provide him with means of estimating the level of the coke in the gasifier. A gamma-ray method seemed the obvious choice. A radioactive source was installed, shooting its beam across the gasifier shell with three detectors at different levels on the opposite side. The detectors were arranged to switch lights for high, normal and low levels, thus giving the operator the information he required. The system has been found to operate successfully, but the initially provided radioactive source of 240 mc proved to be insufficiently powerful and had to be replaced by a source of 350 mc.

(b) Oxygen/steam blast control

The regulation of the oxygen/steam blast and the control of the ratio between oxygen and steam presented problems of paramount importance to the success and safety of the experiments. Both components had to be metered and their ratio adjusted over a wide range of flows. The range could only be covered by two orifice plates in each line. The orifice plates were calculated for minimum overlap between the ranges of measurement and were installed in parallel. The arrangement is shown in Fig. 3. To prevent an excessively complicated change-over from one plate to the other, each plate was connected to a separate differential pressure transmitter.

The ratio control was achieved by making the signal from the steam flow transmitter control the set point of the oxygen flow controller. After some initial adjustment the ratio control system proved to be very efficient. In fact, the oxygen flow followed the steam flow so closely that it reproduced, graphically, short-term disturbance ripples appearing on the steam flow recorder. The steam flow, which was the leading flow, was adjustable by means of a rheostat-controlled valve whose position could be varied by means of a knob provided on the main control panel. Both valves used in the system were standard diaphragm-operated equal percentage control valves fitted with relays in which the electric control signals were converted to standard air pressure signals in the range of 3 to 15 p.s.i. Because of the hazard attached to an incorrect functioning of the flow ratio control system, special precautions had to be adopted during the start-up of the plant. The flow of steam and oxygen was initially vented to the atmosphere so as to enable the flow ratio control system to bring itself to a state of balance. As soon as a steady control condition was observed the flows of steam and oxygen were switched to the tuyere

by a simultaneous operation of two three-way cocks.

(c) Slag discharge problem

One of the difficult problems which had to be solved was the continuous removal of slag from the quench chamber of the gasifier. Various systems were considered and finally it was decided to discharge the slag in the form of slurry in water and to recover the water and recycle it to the gasifier. This method posed a difficult problem of dropping the pressure of the abrasive slurry from the full pressure of the gasifier, *i.e.* 100 p.s.i. down to atmospheric pressure. It was eventually established that a length of pipe could be used to dissipate the 100-p.s.i. head, but some difficulty was experienced due to the pipe becoming blocked with lumps of coke which were dropping from the gasifier hearth together with the molten slag. The fritting of the slag occurred in a basket through which water was circulated at a rate of 5 to 10,000 gal./hr. using reciprocating pumps. The total water content of the quench chamber was maintained constant by controlling level at the bottom of the gasifier shell using a differential pressure measuring system and a control valve installed on the by-pass of pumps 17.

(d) The product

Make gas left the gasifier shell at a temperature of about 600°C. It carried dust and vaporised tar. Most of the impurities were removed by means of a venturi scrubber followed by a hydrocyclone where the water carrying the dirt was separated from the gas and returned by gravity to the bottom of the gasifier from which it was discharged together with the slag. The head of liquid in the return line was equivalent to the pressure difference between the top and the bottom of the gasifier. In the case of blockage in the return line the liquid level in the pipe would rise right up to the hydrocyclone. A level indicating alarm was installed to detect such a defective condition.

The gasifier pressure was measured at the point of off-take and controlled automatically using control valve G.3. The control of the gasifier pressure was basically easy because of the great volumetric capacity of the system. In this particular case it was necessary to use a wide proportional band and some integral control action so as to avoid any sudden changes in the position of the control valve, and in particular rapid closing of the control valve. This was important in order

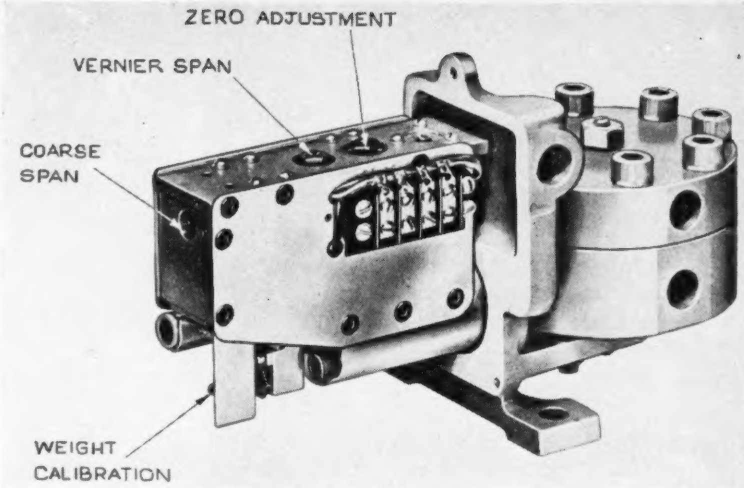

Fig. 4. D.P. transmitter with cover removed.

to prevent the building up of a differential pressure between the hearth of the gasifier and the quench chamber. Any fluctuations in the upper part of the gasifier had therefore to be sufficiently slow to enable the nitrogen purge in the quench chamber to always maintain there a slight positive pressure.

The pressure control system worked satisfactorily, but some difficulties were experienced with the control valve which suffered the attack of corrosion on the stainless-steel plug, seat and the guide poles. Blockage was experienced due to lumps of coke, carried over with the make gas, falling into the valve body. Much of the trouble originally experienced was due to an unsuitable position of the valve in the make gas line.

(e) Monotube boiler

The purpose of the monotube boiler was to provide adequate cooling for the walls of the gasifier hearth. The tube was coiled round the hearth in the form of a conical spiral. Water was pumped into the coil using pump 26. Under normal conditions most of the water evaporated in the tube. Any remaining water was separated in drum 59 and was recycled to the boiler tube. The steam which was generated could be used in the steam oxygen blast, but in practice it was found more convenient to vent it to waste. A back-pressure controller was used to maintain the required pressure in the boiler system. Water make-up to the boiler was provided by a constant-speed, variable-throughput pump 26A working under the control of L.R.C.A.

Level was measured by the differential pressure method and the controller was capable of varying the throughput setting of pump 26A by means of an air diaphragm operator fitted with an electric-to-air signal transducer. In spite of the apparent simplicity of the level control system it was found difficult to control a fixed level in the drum. Sudden and unexpected changes of level were observed and it was apparent that the control system had difficulty in catching up with the observed variations. The performance of this control loop was also observed to be dependent on changes in steam pressure. The only logical explanation one could offer was that, of the total volume of the boiler tube, a variable fraction was occupied by water as the rate of steam generation was not constant. Thus it could be assumed that the boiler tube would sometimes fill with water and then discharge most of its water content into the drum within a short space of time causing sudden fluctuations of level which were beyond the corrective power of the control system.

Data collection system

In order to enable the plant to produce the maximum amount of technical data a large number of measuring devices were installed to check the performance of the various stages of the process. Extensive facilities were also provided for the centralised indication, graphical recording and digital logging of the many measurements. Generally speaking, the measurements could be classified in terms of the method employed to obtain them.

(*a*) *Temperature measurements*

Temperatures were measured at points indicated on the flowsheet by the symbol TR; all temperatures were measured by thermocouples. The most important temperatures were displayed on miniature recorders mounted on the main instrument panel. All the temperatures were recorded digitally by the automatic data logger.

(*b*) *Pressure flow and level*

Electric transmitters were used for pressure and differential pressure measurements including liquid level in the gasifier and in drum 59. Fig. 4 illustrates a typical transmitter. The instrument uses a diaphragm as a sensing element and a differential transformer as a means of generating the transmission signal. The signal is 0 to 0.5 V a.c. and is fed to an electronic miniature recorder illustrated in Fig. 5. Since air-operated control valves were used throughout, each valve had to be fitted with a standard converter which transformed the electric signal into a 3 to 15-p.s.i. pressure signal. This type of instrumentation is standardised in such a way that any receiving instrument can be connected to any transmitter and any valve to any control unit. This type of electronic instrumentation is convenient for pilot-plant work where extensive modifications and rearrangements of the system are inevitable and where calibration checking is required before each experimental run of the plant.

Because of the varying operating conditions which are typical of a pilot plant some difficulty was experienced with the interpretation of the readings of orifice-type flow meters. To facilitate the task of the operator, graphs were devised which enabled a rapid interpretation of instrument deflections in terms of actual flow. Fig. 6 illustrates such a graph which was prepared to cover the measurement of make gas flow for pressures between 20 to 120 p.s.i., temperatures between ambient and 600°C. and specific gravities between 0.4 and 1.0. Three flow metering nozzles were installed in parallel to cover adequately the wide range of gas flows which had to be measured. Each nozzle was connected to a separate differential pressure transmitter and, because of the relative inaccessibility of the metering manifold, the diversion of the gas flow to the appropriate flow nozzle was performed by means of air-cylinder-operated cocks controlled by a rotary switch on the main instrument panel. The same rotary switch connected the output of the appropriate differential pressure transmitter to the flow recorder on the panel.

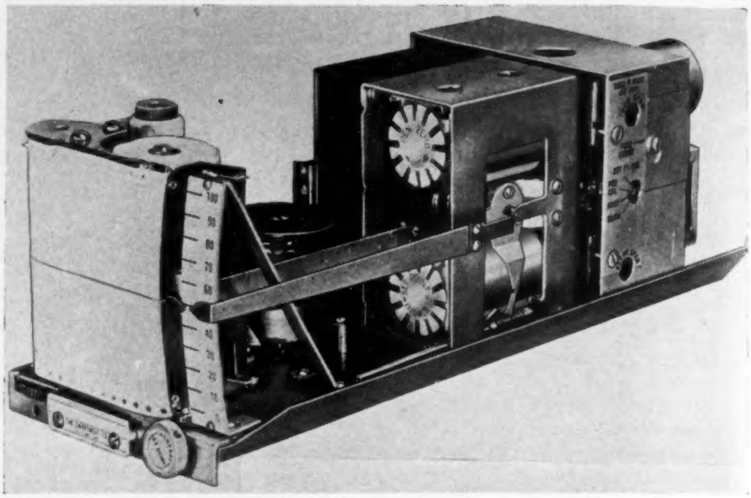

Fig. 5. Miniature electronic recorder with cover removed.

(*c*) *Gas analysis*

Measurements of gas composition were carried out at two points of the plant:

(1) At the make gas outlet from the gasifier in order to gauge the quality of the product.

(2) In the slag quench chamber for reasons of safety.

Both samples were hot, moist and dusty and had to undergo some treatment before admission to the analysis instruments. The system which was developed for the sampling, analysing and calibration of meters is shown in Fig. 7. The two gas samples which arrived at the reducing valve had already been filtered through glass wool and passed through a cooler where most of the moisture had separated. The pressure was reduced to about 2 p.s.i. using a stainless-steel self-acting reducer, followed by a relief valve for the protection of the system in case of mal-operation of the reducing valve. The samples were then passed through calcium chloride and copper sulphate absorbers for the removal of water vapour and H_2S respectively. The suction pumps which could be switched in and out of the circuit were only used during start-up when the gasifier was operating under suction or under atmospheric pressure.

The system of selective cocks was designed to enable any analyser to be connected to either of the two sample streams or to a standard gas sample for calibration purposes. Valves K.1 and K.2 were used to adjust the back pressure in the sample manifold so as to obtain an adequate flow to the individual instruments. Only a very small fraction of the total sample was passed through the instruments. The majority of the gas drawn from the plant was discharged to the vent line. This system enabled faster speeds of response to be obtained by increasing the linear velocity of gas flow in the pipe connecting the plant with the gas analysis room. The speed of response of the gas analysis system was an important factor particularly during start-up when a break-through of oxygen to the upper part of the gasifier was more likely to occur and to create a hazardous condition. The normal delay caused by the sampling system illustrated in Fig. 7 with 100 ft. of pipe connecting the analysis room with the plant was found to be 40 sec. It was found that one of the main causes of delay was the large capacity of the calcium chloride and copper phosphate absorber bottles. When a higher speed of response was required during the start-up of the plant these bottles were replaced by small-capacity absorbers which reduced the sampling delay to 8 sec.

Infra-red absorption analysers were used for the measurement of carbon monoxide, carbon dioxide and methane contents. These instruments were of the laboratory type and required more frequent re-calibration than some industrial-type instruments which are available. The instruments which were used proved satisfactory and accurate to $\pm 2\%$ of full-scale deflection provided calibration checks were carried out at approximately 1 hr.

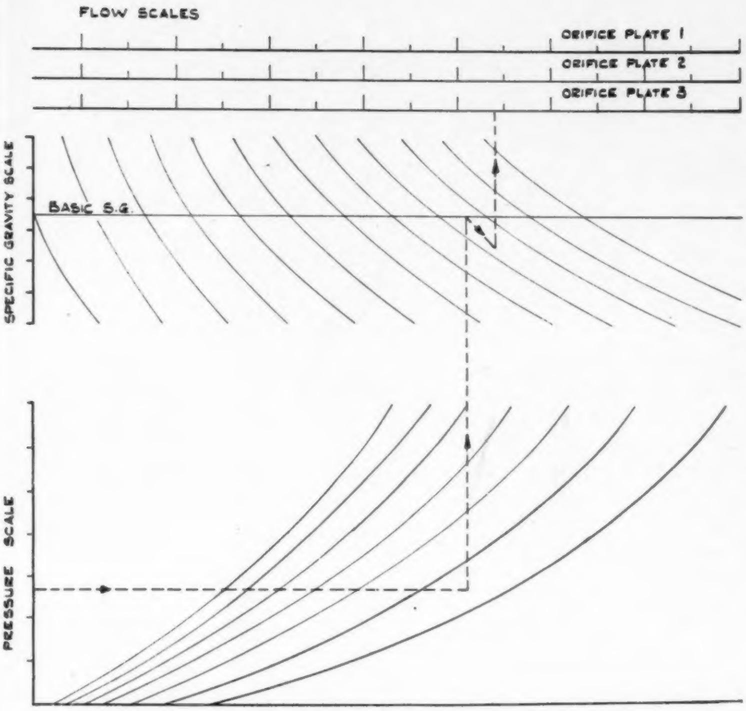

Fig. 6. Flow correction chart.

intervals. For the measurement of hydrogen content a novel instrument was used in the initial phase of experiments. This instrument worked on the principle of comparing the speed of sound in the gas mixture with the speed of sound in air. The resulting measurement is basically a measurement of specific gravity or average molecular weight of the gas mixture. Hydrogen content may be calculated on the basis of this measurement taking into consideration the specific gravity of the remaining mixture of gases. The method is basically sound but inconvenient, due to the calculations involved in the interpretation of readings. The sonic instrument was eventually substituted by a catharometer which gave a direct reading of hydrogen content. The catharometer was calibrated on the basis of a typical composition of the remaining components of the mixture.

The determination of oxygen content was the most critical of all the analyses since, as already mentioned, the safety of the plant depended on the percentage of oxygen in a mixture with combustible gases. Oxygen content was measured using the magnetic wind principle. The instrument had a full-scale calibration of 0 to 5% by volume. It was considered that the plant could operate safely with an oxygen content of up to 2% in the make gas. Higher percentages of oxygen could be tolerated in the quench chamber. Every analysis instrument was arranged to give a local indication of its reading in the analysis room and to transmit a corresponding d.c. signal to a multi-point strip chart recorder on the auxiliary panel in the control room. The oxygen meters were fitted with high-oxygen-content alarm contacts.

(*d*) *Liquid oxygen stock measurement*

Liquid oxygen was stored in spherical vessels each containing 2 tons of oxygen. In order for the chief plant operator to have a continuous check on the quantity of oxygen in storage, a system of quantity measurement was installed using a remote weighing technique. A hydraulic load cell was installed under one of the three points of support of each spherical vessel. The load cell consisted of a capsule containing a hydraulic fluid. The pressure of the fluid was transmitted by a standard electric pressure trans-

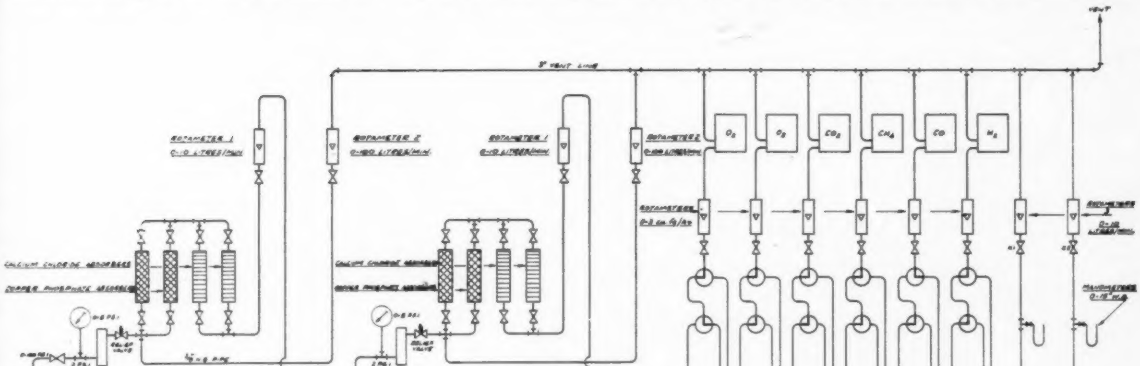

Fig. 7. Gas analysis sampling system.


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mitter to an indicator on the main instrument panel and also to the data logger. An off-set was introduced in the calibration of the transmitter so as to compensate for the weight of the empty vessel. The load cells caused some difficulty at commissioning due to leakage in the hydraulic system. This trouble was, however, cleared and the system was made to operate satisfactorily.

(*e*) *Digital data logging*

The purpose of the data logger was to collect all the measurements which were transmitted from the plant, convert them to digital form and to present them on a log sheet and on punched tape. The total number of transmitted measurements was about 85, many of which do not appear on the simplified flowsheet. Using the full capacity of the recorders which were installed in the control room, only a fraction of the total number of measurements could be recorded graphically. The data logger therefore provided means for the recording of all the measurements, of which the more important ones could also be presented in graphical form. Apart from the log sheet and punched tape method of presentation the data logger included a luminous digital indicator on which any selected variable could be displayed on demand. This indicator could only be used when the electric typewriter and the tape punch were at rest. Automatic logging could be carried out continuously or, alternatively, one complete set of data could be printed out at selected intervals of time.

The measurements which were fed to the logger were classified into groups according to the nature of the electric signals, *i.e.* d.c. and a.c. voltages, which were further segregated into signals bearing a linear relationship to the measured variable or non-linear signals such as generated by differential - pressure - type flow transmitters or thermocouples. These various types of inputs required individual processing and transformation to a standard type of signal, also linearisation and scaling, before the final result could be printed out on paper. Special circuits were available to provide the necessary functions and each signal having been selected by a central programming unit was automatically routed through the appropriate circuits.

Conversion from analogue to digital form was achieved by means of a mechanical digitising disc designed for a discrimination of one in a thousand.

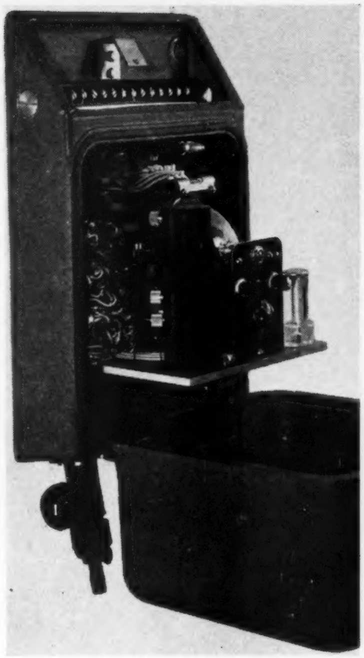


Fig. 8. Oxygen analyser transmitter.

This high degree of discrimination coupled with the high speed of operation of the digitiser proved to be a drawback due to the random noise in some of the signals, which was found to be of the order of 15/1,000. This applied in particular to signals generated by pressure and differential pressure transmitters which were sensitive to mechanical vibration and to high-frequency random fluctuations in the measured variable. Due to the presence of the noise in the measurement signals the last digit kept changing at a high rate and could not really be taken into account. It was also sometimes impossible for the digitiser to come to even a momentary state of balance, which was essential for its position to be decoded. To prevent the logger from stopping at such a point an override device was incorporated which made the machine omit the printing of any point on which the digitiser could not come to balance. The scaling of readings was so arranged that each variable was printed out as an actual value of flow, pressure, etc. This was found to be an inconvenience when operating ranges of pressures and flows were changed. The measuring transmitter could easily be recalibrated to a new range of measurement, but the change of scale on the appropriate point in the logger proved to be a complicated operation. This difficulty only applied in cases where transmitting instruments were used and not in the case of thermocouples where a fixed relationship exists between the temperature and the output signal.

Commissioning of data logger

Many difficulties were experienced during the commissioning of the data logger. One of the main difficulties was the frequent failure of the electric typewriter, which apparently could not cope with the originally specified rate of logging at 1 point/sec. The performance of the typewriter improved when the rate of logging was reduced. Difficulties were also experienced as a result of the unreliability of electromagnetic relays and electronic valves. On the whole, it could be said that experiments with automatic data logging yielded negative results. It should be borne in mind, however, that the machine was one of the first installed in this country and that some considerable progress has been made since in the development of data logging techniques. The general lesson which could be learnt on the subject of data logging could be summarised as follows:

(1) The discrimination specified for a digitiser should be the minimum required for the particular application and should be consistent with the accuracy and stability of the transducers.

(2) In the case of noisy signals, the effect of noise should be eliminated, using suitable damping or integrating circuits built into the data logger.

(3) The speed of operation should not be greater than that effectively required. This will reduce the wear and tear of equipment and minimise the number of failures.

(4) When used on an experimental pilot plant, all the readings of signals generated by measuring transmitters should appear as 0 to 100% of full-scale calibration. This will enable changes of transmitter calibrations and sizes of orifice plates or other primary devices to be modified as necessary, without the need to make any alterations to the logging machine.

(5) The equipment should be constructed in modular form and in such a way as to enable an easy recognition and quick replacement of sub-assemblies which may have become defective.

Television

Correct slagging conditions at the tap hole were essential to the proper performance of the plant. Various difficulties were observed such as the formation of beards or slag icicles which were due to either imperfect mechanical design or incorrect operation of the plant. Slagging conditions can be controlled through suitable adjustment to the steam/oxygen blast. For this reason and for reasons of safety it was decided to employ closed-circuit television for the observation of tap hole conditions. A television camera was installed on a tripod and sighted through a nitrogen-purged sight glass. A 14-in.-screen display unit was mounted on the main control panel. The performance of the TV system was found very satisfactory and, in fact, the picture obtained on the TV screen was superior to that obtained by direct eye observation. The results were, however, dependent on visibility conditions inside the quench chamber. The visibility was sometimes very poor due to silica fumes which formed, principally as a result of pressure variations inside the gasifier. Some experiments were carried out using infra-red filters to improve the quality of the picture under 'fogging conditions', but the results were not really positive.

Safety and alarm systems

The safety of the plant and personnel was safeguarded by a number of alarm devices associated with some more critical functions of the process. An emergency shut-down system was devised which came into operation as a result of one of the following:

(*a*) A complete failure of electric power supplies.

(*b*) A failure of the compressed-air supply system.

(*c*) A manual operation of two emergency shut-down push-buttons on the main control panel. Two emergency shut-down buttons had to be depressed simultaneously to put the shut-down system into operation. This was to avoid an unintentional shut-down to be caused by the accidental pressing of a single push-button.

A stand-by source of power was provided in the form of diesel-driven generators which were running whilst the plant was in operation. An instantaneous change-over system was installed to ensure a continuity of supply.

The general plant shut-down was initiated by the operation of an automatic cock which completely vented the compressed-air supply to all control valves. As a result of complete loss of air pressure, all valves adopted fail-to-safety positions determined by the function and design, *i.e.* the oxygen control valve closed, the steam control valve opened, the make gas valve was locked in its last position, the monotube boiler make-up water pump governor adjusted itself to maximum throughput and the steam let-down valve opened. At the same time the operation of the cycle controller was arrested so that no more fuel could be admitted to the gasifier.

Alarms for critical functions on the plant were provided as shown on the flowsheet. Alarms associated with pressures, flows or temperatures recorded on miniature chart recorders were derived from limit switches fitted in these recorders. In the fuel handling section of the plant, various solid level detectors were fitted to warn the operator of high and low levels in bunkers and hoppers. Diaphragm-operated switches were mounted on fuel bunkers. These are simple devices in which the alarm switch is operated by a rubber diaphragm under the pressure of the solid material. These level switches were found satisfactory but not accurate, as sometimes the level had to build up to 5 ft. above the diaphragm before the switch operated. It was recognised that the high coefficient of friction of coke coupled with low density may have been the cause of this phenomenon.

Electrical capacity probes were used in hopper No. 8 and in the lock hopper and proved to be entirely reliable. The operation of the probe in the lock hopper was interlocked with the operation of the cycle controller in such a way as to impede the progress of the cycle should the charge remain in the hopper after the opening of valve F.4. A flame failure alarm system was installed in the combustion chamber at the bottom of the stack. The system which was used was based on the principle of conductivity of a flame caused by the ionisation of gases at very high temperatures. Three metallic electrodes were installed at suitably selected points in the combustion chamber and the electrical resistance values between these electrodes and earth were detected and made to operate electronic relays. The three electronic relays corresponding to the three probes were connected in parallel in such a way that the flame failure alarm in the control room was not actuated until all the three electrodes showed a condition of flame failure.

Alarm signals were displayed audibly by a buzzer in the control room and, visually, by a luminous annunciator in the main instrument panel. On the occurrence of an alarm condition the sound of the buzzer was accompanied by a light flashing behind the appropriate frame of the annunciator. Upon the pressing of an acknowledgment button the buzzer was silenced and the light changed to steady. A test button was also provided for the simultaneous checking of all the lamps. The danger of lamp failures was reduced by the fact that two lamps were provided behind each frame and the failure of one could be noted by a reduction in brilliance.

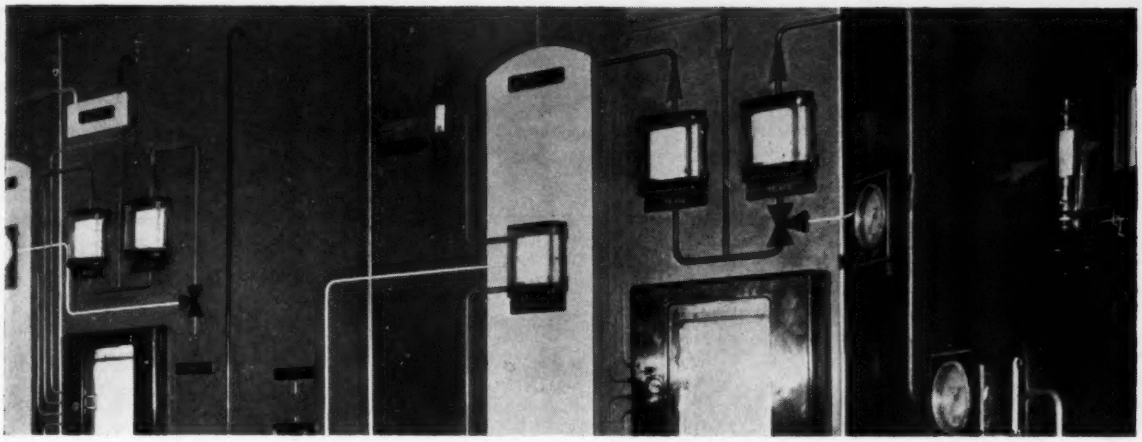
Maintenance

The maintenance of equipment on a pilot plant which is subject to frequent modification presents problems which are different to those on a normal production unit. Generally speaking, a routine schedule of maintenance is replaced by a pre-run inspection of all equipment and checks of instrument calibrations. Instruments generally give a better performance when continuously in use. This particularly applies to electronic instrumentation where the number of valve failures tends to be greater when equipment is being switched on and off. Many pilot plants are not operated continuously, under which circumstances instruments have to be recalibrated more frequently than would otherwise be necessary.

As the plant is modified and developed, the instrumentation system needs frequent alteration. The pilot plant described in this article provided full-time occupation for one instrument engineer and one instrument mechanic with part-time services of an electrician. This team covered all aspects of work, *i.e.* calibrations, repairs, design and execution of modifications and attendance during the experimental runs. An instrument engineer working on a pilot plant finds many opportunities for experimenting with the various techniques which he is using and for the accumulation of experience in their improvement. The knowledge which is thus accumulated is of immense value in the design of the full-scale plant.

Acknowledgment

The author wishes to thank the Ministry of Power, and Constructors John Brown Ltd., for permission to publish this article. Acknowledgment is also made to Elliott Bros. (London) Ltd., George Kent Ltd. and C.J.B. Ltd. for the use of photographs.



Instrumentation of Chlorosilanes Distillation Plant

By D. B. Whitehouse,* B.Sc., Ph.D., A.R.I.C.

The chlorosilanes distillation plant at the Barry works of Midland Silicones Ltd. has to separate more than a dozen chlorosilanes used in the manufacture of various silicone products. In order to achieve this, seventeen columns each having a large number of plates are required to distill pure chlorosilanes, having relatively close boiling points, from their mixture. By extensive use of automatic instruments in the process control, described in this article, this plant is operated most efficiently by only two men.

MORE than a dozen chlorosilanes are used in the manufacture of the numerous silicone products which are commercially available, the most important of them having one or more methyl or phenyl groups attached to the silicon atom. Broadly speaking, silicones are made by the controlled hydrolysis and polymerisation of different, carefully blended mixtures of chlorosilanes. Each chlorosilane in the mixture must be of a very high degree of purity in order that such blends can be accurately made up to include the correct amounts of, for instance, mono- or tri-functional compounds, which provide cross-linking and chain end blocking respectively in the polymers. Slight variations in the hydrolysate composition have a profound effect on the properties of the finished product. The chlorosilanes in commercial production are made in a number of ways but this article will deal only with the separation by distillation of pure methyl chlorosilanes from the crude mixture manufactured by the direct reaction of silicon and methyl chloride.

It will be noted from the flow diagram (Fig. 1) that the useful chlorosilanes in the crude mixture have relatively close boiling points and, to produce the pure compounds, the distillation columns have a relatively large number of plates and operate at high reflux ratios. To keep steam consumption to a minimum and yet obtain the necessary separations, the columns must be operated at high efficiencies. The distillation plant at Midland Silicones Ltd. has 17 columns and is operated by two men. This has been achieved by making the operational control of the columns as nearly automatic as possible in order to keep the top and bottom products of each unit of consistently good quality.

Properties of chlorosilanes

It is necessary to appreciate some of the properties of chlorosilanes which influence both the choice of control systems and the materials and methods of construction of plant items and instruments:

(1) Chlorosilanes in general have low flash points. The plant used for handling them must, therefore, be flameproof.

(2) Chlorosilanes are readily hydrolysed to give hydrogen chloride and a variety of silanols and siloxanes depending on the conditions of hydrolysis and the chlorosilane concerned. Quite apart from the corrosive properties of hydrogen chloride, the products of hydrolysis may be liquids, semi-solid gels or silica-like solids which can themselves

*Midland Silicones Ltd.

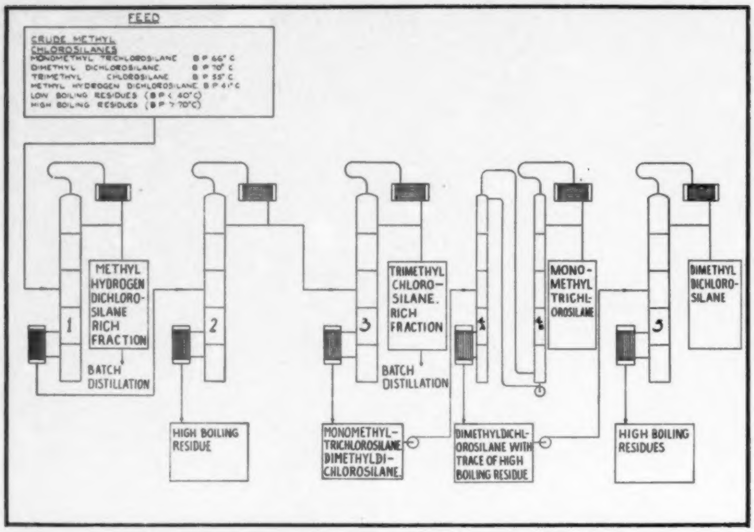


Fig. 1. Flow diagram of distillation plant for methyl chlorosilanes.

cause troubles, such as control valve blockages and seizing up of mechanical parts. Moisture must, therefore, be rigorously excluded and, because of the low flash points and the possible presence of auto-igniting bodies, such as dihydrogendichlorosilane, dry inert gas (nitrogen of dewpoint –50°F.) is used for pressurising and purging equipment handling chlorosilanes.

(3) Provided moisture is excluded, mild steel and cast iron are unaffected by chlorosilanes and, although it is not necessary to use stainless steel, this can be used, if required, for special purposes such as magnetic-type instruments and control valve trim.

(a) Separation by continuous distillation

As shown in the flow diagram (Fig. 2), the crude reaction product of silicon and methyl chloride contains mono-, di- and trimethyl chlorosilanes and methyl hydrogen chlorosilane together with traces of trichlorosilane, silicon tetrachloride and small quantities of compounds boiling below 40°C. (low boiling residues) together with traces of numerous compounds boiling above 70°C. (high boiling residues). The amount of any particular component in the crudes can be varied within limits, but in general the crudes for distillation are of fairly constant composition.

A train of five distillation columns is used to separate the crudes into pure mono- and dimethylchlorosilanes, to remove high boiling residues and to produce trimethyl- and methyl hydrogen chlorosilane-rich fractions. Pure products are produced from the latter two fractions by batch distillation. The sequence of operations is shown in the flow diagram. The first column in the train removes methyl hydrogendichlorosilane and low boiling residues overhead and the instrumentation of this column is shown in some detail as a typical example of the equipment used. Variations on this theme to meet specific requirements of other columns are dealt with later.

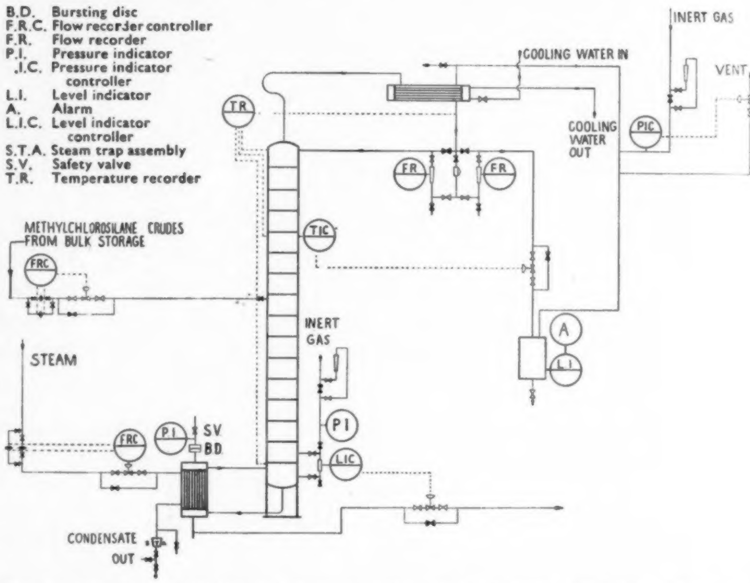


Fig. 2. Diagram showing typical instrumentation on a continuous distillation column for chlorosilanes.

All the site instruments are totally enclosed and the 'air leaks' from the flapper and nozzle devices are sufficient to keep the instruments purged to exclude any chlorosilanes which may escape into the atmosphere from time to time. Readings from all instruments are transmitted to a panel in the plant control room and all controllers and control valves are pneumatic.

Heat supply

The quantity of steam supplied to the reboiler is set manually on the steam flow recorder controller to give the desired boil-up in the column. The flow is measured on site by an orifice plate and differential pressure cell.

Feed control and reflux

The feed to the column is set manually on the flow recorder controller to give the required throughput. The flow is measured on site by an orifice plate and differential pressure cell.

The reflux and top product flows are measured by site indicating and transmitting rotameters with recorders on the panel.

Reboiler level and top product

The level of liquid in the reboiler is measured by a sealed level buoy on site, the value being indicated on the control panel. Bottom product is taken off when indicated level rises

above '50%', the output of the controller operating the control valve in the line from the reboiler to the next column. Conversely the bottom take-off control valve is closed as the level falls below '50%'. The off-take of top product is controlled by sensing the temperature at a point in the column found by experience to be where temperature is most sensitive to composition changes. The actual temperature below which top product is taken off is also found by experiment and the amount of top product taken off is regulated by the sizing of the control valve so that the reflux ratio does not fall below the required minimum.

Temperature and pressure

In addition to the temperature point used to control top take-off, temperatures are also measured at the bottom of the column, near the feed point, at the top of the column and in the condensate, and recorded on a multipoint recorder on the control panel.

Product tank levels are measured on site by level buoys and indicated on the panel; high-level alarms are fitted.

Column bottom pressure is indicated on the panel by measuring the pressure required to allow 2 cu.ft./hr. of inert gas to flow through a purge into the level buoy housing. Where a column operates under pressure greater than atmospheric, a similar purge is fitted to the condenser; the pressure in such a column is controlled by a vent control valve fitted to the condenser and actuated by the top pressure indicator controller.

Variations on the theme

(1) The second and fifth columns in the train differ from the others because the volume of bottom product from each column is small compared with the overhead product. Bottom take-off (of high boiling residues) in these cases is controlled on bottom temperature and top take-off is controlled on bottom level with a reset device to prevent top product from being taken off, if the bottom temperature is above the figure at which bottom product would normally be removed.

(2) The fourth column is divided into two because of its large number of trays and reflux from the base of the 'top half' is pumped through a control valve (operated by a level indicator controller in the bottom of 'the top half') to the top of the other part of the column.

(b) Separation by batch distillation

A typical Raschig ring packed batch column is shown in the diagram (Fig. 3) and the following are the details of instrumentation.

Heat supply and pressures

The steam flow is controlled by a steam recorder controller which can be set manually or reset by the differential pressure measured across the column.

The top and bottom pressures are measured using similar means to those employed on the continuous columns, and differential pressure is measured across the column. This value is recorded and is used to control the steam supply to the still-pot.

Top product

Top product is taken off through a control valve manually operated from the control room and to a cut tank selected by a manual valve at the product manifold on site. It was originally intended that cut tanks should be selected from the control room, but considerable difficulty was experienced because the control valves to individual tanks tended to pass small quantities of material when closed, thus contaminating the fractions that had been collected.

Temperatures, reflux and take-off flows are all measured and recorded on batch columns as described for the continuous columns.

Process control

(a) Continuous distillation

Many of the symptoms of faults which may occur from time to time on continuous distillation columns show up on the instrument panel and it is vital, therefore, that plant operators should be able to appreciate any deviations from normal conditions. All column instrument readings are recorded hourly on log sheets to ensure that frequent and full attention is paid to the instruments by the operators. The instrumentation provided is such that a fault on one instrument will usually be detected by noticing abnormal readings on the others.

As an instance of this, let us assume that the level buoy on the first column sticks in its housing, in a position which indicates a low level. Because of this apparent low level, the bottom take-off control valve will remain closed and, as a result, the reboiler and the bottom of the column will start to fill with liquid. Gradually the indicated bottom pressure will increase as the level builds up and the bottom temperature will also start to rise. These facts and an observation that the level indicator is showing no movement at all lead one to the conclusion that the level buoy is not operating freely.

Again, if we assume that some fault develops which prevents the top take-off control valve from opening. the temperatures throughout the column would fall, starting with the upper temperature point, because low boil-

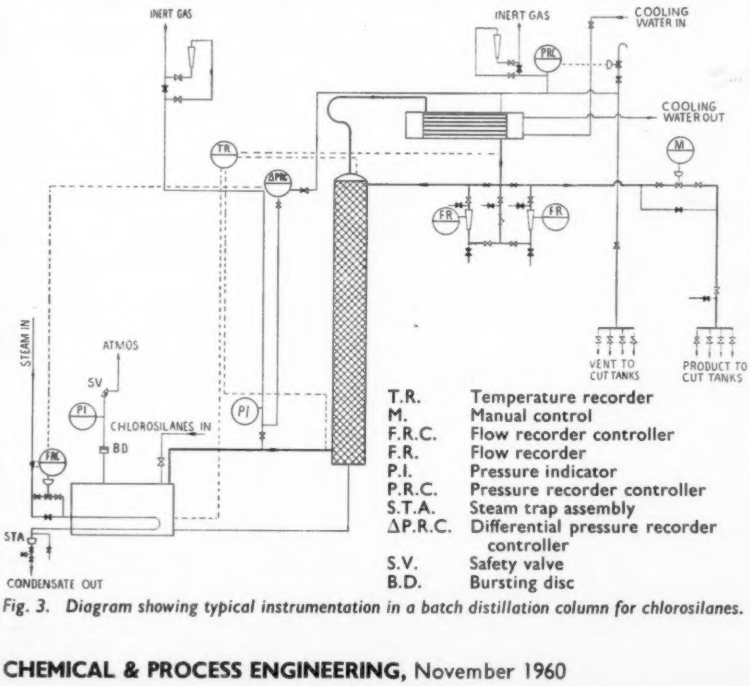


Fig. 3. Diagram showing typical instrumentation in a batch distillation column for chlorosilanes.

ing compounds would be accumulating in the column. Such a symptom could easily be confused with an increase in the content of low boiling material in the feed, but the remedy of reducing the feed rate (which would be effective in the case of a change of feed composition) would, of course, make no difference to the column, if the take-off control valve were failing to open. If the temperature at the bottom of the column started to fall, then a failure to take off top product would be suspected at once.

The instrumentation for the first three columns, in the continuous train which has been described, is quite sufficient to control the composition of the top and bottom products from each of the columns. Once the top control temperatures have been set, the composition of the fractions is sufficiently constant to obviate the need for analytical control. The off-takes from both the top and bottom of the fourth column are each required to be of purity better than 99%, and a check on the composition of these products is taken every 4 hr., using infra-red analysis to ensure that the specifications are being met. If the plant were processing chlorosilanes on a scale such as is common in the oil industry, then a continuous analyser for the top and bottom products would be an ideal device for controlling the operation of this column.

(b) Batch distillation

The control of batch columns distilling chlorosilanes involves the switching of fractions of suitable composition to appropriate cut tanks. The composition of the product being taken off is approximately indicated by the temperature at the top of the column and the specific gravity of the fractions and, for mixed cuts, these data alone are often sufficient. Infra-red analysis of the off-take is essential to ensure that pure products are within the required specification.

Column top temperature is measured continuously and, corrected for top pressure, is used as a first rough indication of product composition. Specific gravity checks and infra-red analyses are carried out on samples taken at suitable intervals during the distillation; they are taken frequently when a change of cut is near.

Specific gravities of the methyl chlorosilanes which are batch distilled vary from 0.8 to 1.5 and in any particular distillation the specific gravity of the fractions may cover more than two-thirds of this range. Ideally, specific gravity should be measured continuously, but no single commercial instrument which has been tried has been fully satisfactory, except to give a very rough guide. A glass box, fitted with a range of hydrometers and a thermometer, and placed in the take-off line has been tried as a means of indicating specific gravity continuously on site. However, as a result of several of these devices leaking or bursting, it was felt that they were unsafe for use on chlorosilanes at a pressure of 25 p.s.i.g., which is frequently used in such distillations. It has been found that frequent samples have to be taken, in any case, as a check on the specific gravity measured by an instrument, so there was little point in having such an instrument.

Variations in specific gravity with different cuts and different batch distillations also present problems in indicating levels and transmitting the value of the level to the control panel. It is not always convenient to use a particular tank for any particular mixed cut, and the cuts are likely to vary in specific gravity from batch to batch. Load cells are not favoured for various reasons and, as most types of level gauge require a constant, or known, specific gravity for accurate readings, sight glasses have been employed, but these must be read on site. Quite apart from the setting of lines for the pumping operations involved in loading and transferring of batch column products, more labour is required for process control of any single batch column than for a whole train of continuous columns.

Conclusions

By the extensive use of automatic instruments, process control of continuous distillation columns for methylchlorosilanes is a straightforward matter. The process control of batch distillation columns for these materials is not so amenable to automatic instruments and, therefore, requires more operating labour and more laboratory analytical work.

INDUSTRIAL PUBLICATIONS

Spectrochemical analysis. A leaflet has been issued by Hilger & Watts Ltd. giving details of the *Elpac* with which powder samples for spectrochemical analysis can be packed into carbon electrodes quickly and consistently.

Industrial X-ray. A catalogue which provides in easy reference form the salient features, sizes, prices and stock availability of industrial X-ray materials and equipment from Kodak Ltd. has been published.

Plastic vessels. A well-produced brochure containing information about *Tufplas* tanks and other vessels has been issued by Tough Plastics Ltd. It describes the various types of vessels made from this laminated material consisting of an inner surface of unplasticised PVC with an outer surface of high chemical and thermal-grade polyester resin reinforced by glass-fibre, the two being chemically bonded.

Radiant-jet furnaces. A leaflet of the Incandescent Heat Co. Ltd. describes a new conception in batch furnace design using *Jetube* radiant heating element. The furnaces are said to be suitable for all general and controlled atmosphere heat treatments within the temperature range 700° to 1,000°C.

Flow meters. A bulletin from Schutte & Koertig Co. illustrates and briefly describes a range of precision instruments for measuring and controlling the rate of flow of all types of fluid. Amongst other information mention is made of flow indicators designed for installation in pipelines where it is necessary to determine by visual observation that fluid is flowing in the right direction.

Blending system. Constructors John Brown Ltd. have published a booklet on their electronic *Autoblender* which is said to be a fully automatic, continuous and accurate blending system for all types of liquids. The 'closed-loop' control system which is employed achieves this accuracy by making use of digital techniques.

Acetic acid handling. A booklet on the storage and handling of bulk supplies of acetic acid has been issued by the Distillers Co. Ltd. It deals with such matters as materials for vessels and piping, heating and insulation of glacial-grade tanks, pumps, valves and safety.

Glycerine. The U.K. Glycerine Producers Association has issued a booklet describing the use of glycerine in paints and resins. It also includes useful physical data and specifications of glycerine.

Legislating for Radiation Work in Industry

By L. E. Stevens

Fig. 1. Internal probe method for radioactive leak detection in water main.

The ever-increasing uses of radioactive materials throughout industry has brought in its wake proposals for legislation to ensure adequate safety precautions for personnel. This article discusses the existing and pending legislation and how it will eventually affect safety and efficiency in industry.

RADIOISOTOPES have already proved of value to the chemical and allied industries in laboratories and factories, and wider application of these products is forecast for research and production purposes in the future. That there are certain hazards involved, meriting special precautions, is now common knowledge, but the chemical industry has had much experience in the safe handling and storage of dangerous materials and should take radioisotopes in its stride.

The basic pattern of safety precautions for radiation work in industry is becoming well known in informed circles. Personal exposure to radiation should be kept to a minimum; adequate shielding or adequate protection should be provided; physical surroundings and structural features should be such that protection is afforded, contamination controlled and decontamination facilitated; plant and apparatus should be designed and operations carried out so that these aims are attained; in case of any dangerous occurrence happening, certain planned steps have to be taken; and, to check the efficacy of the precautions taken, regular monitoring of personal exposure and of the environment has to be undertaken. A final and important test is made by routine and special medical examinations of persons employed.

Precautions

Translated into practical terms these means of preventing ill effects involve taking precautions such as the following: the provision of lead or other shielding round sources of radiation; the use of distance as a safety factor, as with the provision and use of remote controls and long-handled trolleys; the covering of benches and the surfacing of floors so that they are smooth and impervious; mechanical exhaust appliances fitted in suitable places; suitable breathing apparatus and personal protection equipment provided for special maintenance and other work involving potential exposure above normal; the check on sources and reporting of lost ones; the use of film badges and instruments for measuring environmental conditions where necessary; and the carrying out of blood examinations as part of a wider medical supervision of precautions. In these ways and others, precautions are taken to prevent trouble and to ascertain if the measures are in fact effective.

Waste disposal

As conventional methods of 'destruction' such as burning do not

destroy radioactivity, special measures have to be taken to deal with waste in all forms if it is at all 'active'. Earlier this year the Radioactive Substances Act, 1960, became law. It applies not only to factories but to all persons who keep or use radioactive materials on any premises used for the purpose of trade, business, profession or any corporate activity and to those who operate or provide a service with mobile radioactive apparatus.

The Act requires that all such persons and bodies shall register with the appropriate Ministry. The general requirement of the Act, which is limited to the discharge of waste in its various forms (if radioactive), is that it will be illegal to accumulate or dispose of radioactive waste except in accordance with an official authorisation.

Apart from this Act other legislation is being made at the moment and the plan of statutory control is emerging. The atomic energy establishments themselves are already subject to Acts of Parliament dealing with safety such as the Atomic Energy Authority Act, 1954, and the Nuclear Installations (Licensing and Insurance) Act, 1959. Various codes of regulations are now being drawn up for ordinary manufacturing industry and, in particular, there are to be two codes of regulations under the Factories Acts; one, already published in draft form, is the Factories (Ionising Radiations) Special Regulations which deals with sealed sources and irradiating machines. The other, which has not yet reached the stage for publication, deals with other sources, *i.e.* unsealed or open sources.

Transport by road

In addition, statutory legislation is promised in due course for transport of radioactive substances by road—to supplement the transport regulations of the authorities which undertake the carriage of goods by rail, post, sea and air. In the more distant future still, legislation is likely to control health and safety matters in research and other laboratories which are not under the Factories Acts and Regulations.

It is already being said in industry that the regulations should have been made before, as radioisotopes are now in use and industry has a right to know what legal requirements it has to comply with. This criticism is prima facie reasonable, but it overlooks the unusual difficulties in legislating for this new subject for the generality of industry. It is not difficult to decide what precautions need to be taken in specific known circumstances, but it is a very different matter to word laws so that they fit the likely circumstances whilst remaining practical, scientifically and technically sound—and legally acceptable.

A good illustration of this kind of difficulty concerns definitions which are indispensable for modern legislation dealing with industry. In a 1948 Act dealing with radiation, 'radioactive substance' was defined as 'any substance which consists of or contains any radioactive chemical element, whether natural or artificial'. This wide definition extends even to the walls of buildings! Such a description is too comprehensive as it includes material of very low specific activity.

Under the new draft factory regulations another definition which does not fall into this trap has been proposed. This is 'any substance which consists of or contains any radioactive chemical element whether natural or artificial and whose specific activity exceeds 0.002 of a microcurie of parent radioactive chemical element per gramme of substance'. Thus materials with very low specific activity are excluded from the effect of the regulations.

As a matter of interest, another approach has been made in the new Radioactive Substances Act. In this Act the composite term 'radioactive substance' is now defined and also the word 'substance' is defined. This is 'any natural or artificial substance, whether in solid or liquid form or in the form of a gas or vapour'. The meaning for practical purposes is clear—although it is strange to define any word in terms of the same word. But, in addition, several hundred words in the Act are used to explain such terms.

Exposure of person

A fundamental practice in occupational radiation protection is the use of two levels of maximum permissible exposure of the person to radiation. The levels themselves are based on the recommendations of the International Commission for Radiological Protection and the Medical Research Council and allow ample margins for safety.

The higher level is allowed to personnel employed in work where there is a radiation hazard and they are subject to a high degree of medical and other control to ensure that their health is not adversely affected. Monitoring devices are worn to enable an assessment of individual dose to be made and careful records are kept of these. In the draft regulations it is proposed that these records are transferred to the man when he leaves a firm's employ so that the next employer can continue to keep the record if the man is still on similar work. Foreseeing the likely loss of some of these records, the regulations also provide for a copy to be given to the factory inspector who will presumably maintain a central register of these.

But in the case of the so-called non-

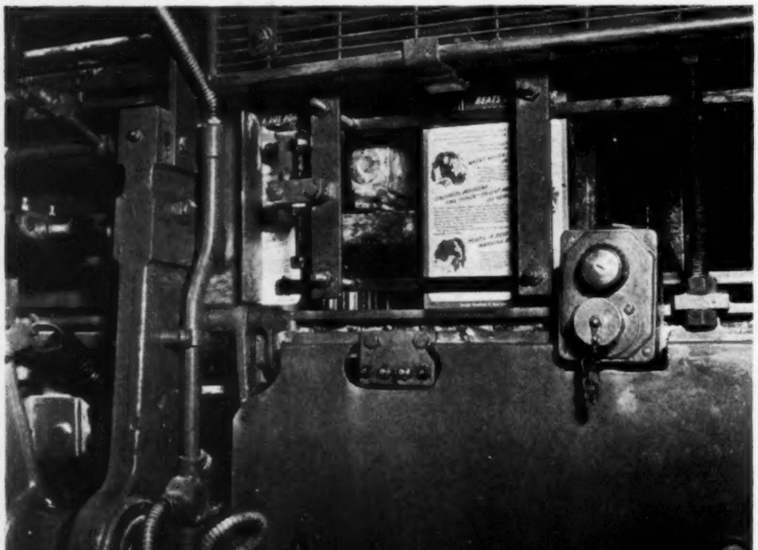


Fig. 2. Uses of radioisotopes for checking contents of cartons, close-up of package monitor at Joseph Crosfield and Sons Ltd.

process worker, a different state of affairs is proposed. Not being subject to the full rigour of the regulations, he is allowed only a fraction of the process worker's dose, but, as the regulations stand, there is no compulsory way of ascertaining what dose the person concerned has in fact had. In the ordinary way an excess may be very unlikely, but it is worth commenting upon a law which lays down a maximum figure and makes no provision for ensuring that the actual figure is ascertained. This may be altered before the final regulations are issued, but careful drafting will be needed or everyone may be burdened with personal monitoring devices—with the consequential administrative and assessment work—and industry could reasonably object to this unnecessary extra load of trouble and cost.

Fig. 3. Uses of radioisotopes for checking contents of cartons, general view of packaging machines and package detector in use at J. Crosfield and Sons Ltd.

Protecting the non-process worker

More thought will need to be given to the whole question of the non-process worker; for the location of a man's place of work in relation to the position of the source of radiation, rather than the man's duties as such, are very relevant. For example, care needs to be given in considering whether some men at present not protected as 'process workers' should have some special protection if they are working in the vicinity of 'active' places of work. A man working at the entrance to a store for 'active' material, or near the fan outlet (even if this only runs occasionally), may profitably be included among those who are medically examined and wear film badges. Alternatively, he could be moved away to a more remote spot.

But these are not the problems in practice that they are when it comes to making precise regulations. In a particular works the person responsible for radiation safety (known under the new regulations as the competent person, but perhaps called the radiological safety officer) can assess the matter and make the most suitable recommendations. Even when the regulations become legally enforceable there is nothing to prevent extra precautions being taken if the expert on site considers this necessary in unusual circumstances.

Ways of legislating

When examining the new draft regulations and other legislation, it is worth remembering that, as was pointed out in connection with the recent Factories Act, there are three ways of legislating. One is by laying down an absolute specific duty; in this case a legal requirement says precisely what shall be done, *e.g.* that the housing of a sealed source shall be distinguished with orange-coloured markings. The second is the absolute general duty which imposes an obligation to provide safeguards against a particular danger without specifying precisely how this shall be done, *e.g.* all dangerous parts of machinery shall be securely fenced.

Reasonable practicability

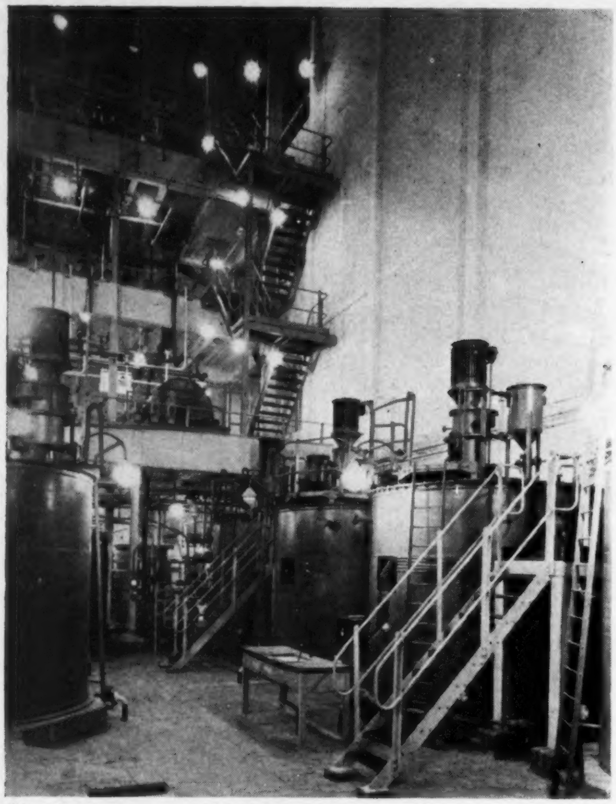
The third is the qualified general duty which is quite distinct from the two absolute duties already mentioned in that there is a qualification to the duty itself. The usual one relates to reasonable practicability; instead of imposing an absolute duty allowing of no exceptions or excuses, it asks for the most that is reasonably practicable in such cases. For instance, 'The occupier shall do all that is reasonably practicable to restrict the extent to which the persons employed are exposed to ionising radiations'. Sometimes other words than 'reasonably practicable' are used, but the principle is the same.

Industrial managements sometimes complain that general, as distinct from specific, legislation imposes a liability upon them without clearly saying what their duty is. In factory law this criticism seems to be truer of Acts than regulations which tend to spell out the duties in some detail. Thus, where the Factories Act calls for 'sufficient' and 'suitable' washing facilities, regulations state exactly how many wash basins are required and their minimum dimensions. Wherever possible, managements quite reasonably want precision in such matters, but in many cases it is not practicable, as is illustrated by the Factories Act requirement that is most commonly used, *i.e.* the one requiring secure fencing for dangerous parts of machinery—it would obviously be impracticable to list every dangerous machine in industry and specify detailed safeguards.

Conclusions

That there are difficulties in legislating in the field of radiation safety must therefore be conceded; there are inherent difficulties in legislating for safety at all and, when the whole of industry with multifarious prospective uses of different radioisotopes in an immense variety of circumstances is contemplated, sympathy must be extended to those who are trying to put these matters into legal terms.

Meantime the use of radioisotopes will continue to multiply and Government and other experts are available to solve the health and safety problems which may arise. Generally the answers are known, but putting them into acceptable legal form is another matter.



'Pitan' coatings protect at Royal Ordnance factory.

CORROSION AND METAL FINISHING EXHIBITION PREVIEW

★ *OLYMPIA* ★

November 29 to December 2, 1960

The Corrosion and Metal Finishing Exhibition is sponsored by the Leonard Hill journal CORROSION TECHNOLOGY. It will be held in the Empire Hall, Olympia, on:

Tuesday, November 29, from 11 a.m. to 6.30 p.m.
Wednesday, November 30, from 10 a.m. to 6.30 p.m.
Thursday, December 1, from 10 a.m. to 6.30 p.m.
Friday, December 2, from 10 a.m. to 4.30 p.m.

Readers of CHEMICAL & PROCESS ENGINEERING will be admitted free on production of the ticket inserted in this issue, or on production of their professional card.

THE purpose of the Corrosion and Metal Finishing Exhibition is to attempt to limit or reduce the expenditure of over £600 million each year that corrosion costs the U.K. alone and to make clear to industry the ways in which this can be achieved.

This year the Exhibition will probably be the world's largest display of anti-corrosion and metal-finishing products and services. Over 120 stands will be open to visitors, and experts from such organisations as the Atomic Weapons Research Establishment, the Department of Scientific and Industrial Research and the Tin Research Institute will be available to answer visitors' questions on corrosion in their respective fields.

Film shows will be held on three of the four days. The unique and varying programme covers corrosion, metal pre-treatment, coatings, etc., and is expected to be most informative for many visitors. Film titles include 'Metal Spraying', 'Flame Cleaning—Removing Rust Prior to Painting', 'Corrosion in Action', 'Must it Rust?' and 'No Rust Here'.

In former years the exhibition has been known simply as the Corrosion Exhibition, but in order to give a better idea of its scope and the purpose it serves, the name has been extended. The exhibition covers paints, plastics, rubbers, galvanising, anodising, electroplating, metal cleaning, colouring, polishing, paint application, phosphating, plastic coatings, metal and paint spraying, resistant metals, cathodic protection, water treatment, inhibitors and protective systems, de-rusting and de-scaling, corrosion-resistant plant linings, pipelines and protection, acid-resisting floors and tanks, specialised packing, and corrosion and metal-finishing testing apparatus. Every important feature of the former Corrosion Exhibition has been retained, the most important change being its promotion to Olympia, Europe's greatest exhibition centre.

In this preview we describe some of the exhibits which will be on view during the Corrosion and Metal Finishing Exhibition from November 29 to December 2 in the Empire Hall, Olympia.

Metal treatment

Featured in the display of the Pyrene Co. Ltd. will be the latest range of treatments for aluminium, developments in the range of low-temperature immersion and the cold *Bonderite* process.

★

The Walterisation Co. will be showing typical applications of their metal surface treatments for the corrosion-protection requirements of industry. In addition to their rust-proofing processes the new decorative and protective treatment for aluminium will be on display.

★

The theme of the Geigy Co. exhibit is the importance of quite small amounts of organic chemicals as additives in metal treatment and finishing processes, all of which are directed essentially towards the prevention of corrosion.

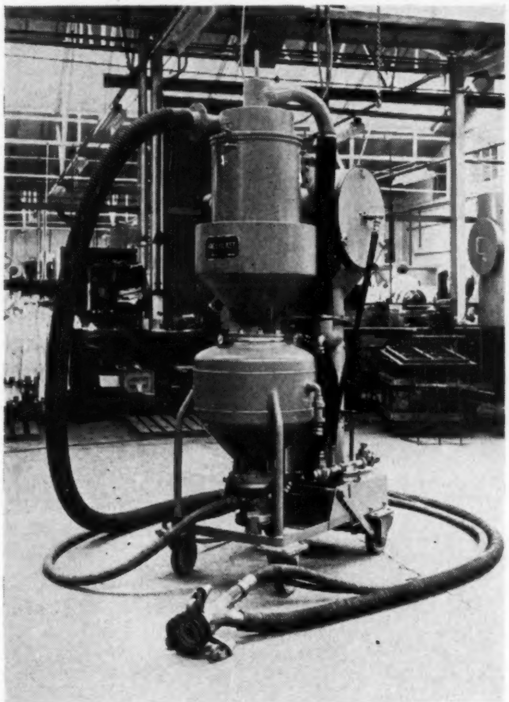
★

R. Cruickshank Ltd. will show their range of bright electroplating processes for both decorative and anti-corrosive

purposes. These include copper, nickel, cadmium, zinc, brass and silver. Also shown will be a non-electrolytic range of treatments.

★

The Atomic Weapons Research Establishment of the U.K.A.E.A. will illustrate a number of varied techniques that are being applied to the solution of specific corrosion problems in the atomic energy industry. The protection of uranium, for example, is being tackled by coating the metal with another more resistant metal such as nickel, the coating being obtained by the decomposition of nickel carbonyl.



Mobile dust-free shot-blast equipment made by Vacu-Blast Ltd.

B.B. Chemical Co. Ltd. are to demonstrate the *Bostik Endurion* process which is described as a non-toxic chemical after-treatment applied to a base phosphate coating. It is said to be valuable for protecting components and mechanisms which are difficult to get at such as car door locks.

★

Examples of various iron and steel components rust-proofed by the *Sherardising* process and also components protected against heat oxidation corrosion and wear by the *Arkrom* chromium diffusion will be shown at the stand of Zinc Alloy Rust-Proofing Co. Ltd. The stand forms a technical information bureau where visitors can obtain details of the processes and the uses to which they can be put.

Coatings

Ciba (A.R.L.) Ltd. will be showing the uses of *Araldite* epoxy resins for protection against corrosion. Examples will be shown of solvent-free coatings which can be applied in thicknesses of up to 0.02 in. Other formulations will include resins for protecting and strengthening the insulation of pipes in chemical plants, and resins for non-slip industrial flooring.

★

C. & P. Development Co. (London) Ltd. will be exhibiting *Rust-Anode*. This is a metal coat which can be applied to steel surfaces by brushing, spraying or dipping. It leaves a coat of pure zinc which is said to be strongly adherent, age-proof and rust-proof.

★

The basic aim of Detel Products Ltd.'s exhibit will be to show that the company's various coating systems have been used in almost all parts of the world.

Paints

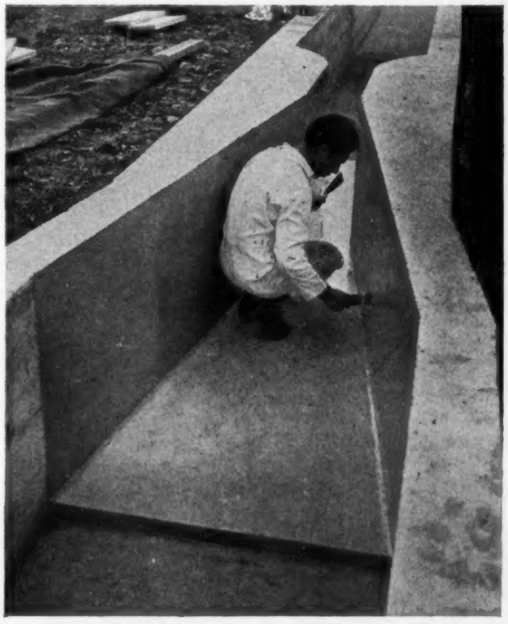
Evode Ltd. will be exhibiting and showing practical applications of *Evokote* range of paints which includes a high-temperature heat- and corrosion-resistant aluminium paint, a high-gloss anti-corrosive paint that can be applied direct to bitumen without the use of sealer, and a clear lacquer for application to hard wood where long-term abrasion and chemical resistance is required.

★

The main object of the Allweather Paints Ltd. exhibit is to show the use of *Pitan* coatings in preventing corrosion of iron and steel work, etc., in industrial, marine and chemical environments. Emphasis is laid on the acid / alkali - resistant chlorinated rubber paint.

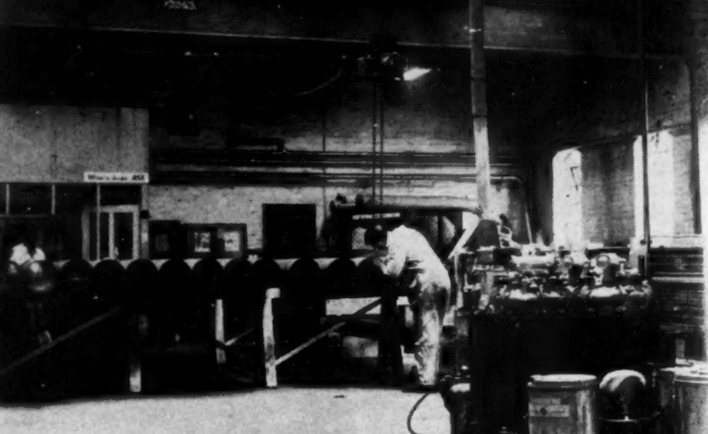
★

On their stand, Drynamels Ltd. aim to illustrate the service they provide to industry as paint manufacturers. Several paints, both old and new, will



1488 'Araldite' coating resin being applied to a flume in a sewage and effluent disposal plant to protect the concrete walls.

be displayed, but stress will be laid on the advisory service which the company provide for paint users.



A new pipelining plant installed at Prodorite Ltd.'s works.

Cathodic protection

A feature of the stand of Metal & Pipeline Endurance Ltd. is a model of a steel jetty illustrating the application of cathodic protection for prevention of corrosion to submerged piles. Instrumentation is available to demonstrate changes in pile potential with changes in applied current density and also to illustrate interference from a cathodic protection system on an adjacent steel structure.

Plant

Vacu-Blast Ltd. will be exhibiting five new machines from their range of mobile dust-free shot-blast equipment and a range of guns and attachments for a wide variety of shot-blast applications. The equipment incorporates a closed-circuit system for blasting and recovery of spent abrasives, dust and debris. The machine continuously separates and cleans the abrasive, the dust and debris being extracted from the air stream and filtered before exhausting to atmosphere.

*

Enamelled Metal Products Corporation (1933) Ltd. will exhibit a glassed-steel drier-blender, in which highly corrosive materials can be dried and blended to produce a homogeneous product with savings in operating times and costs. Drying is achieved by subjecting the product to vacuum and heat, and is speeded by a tumbling action which mixes the materials with an even thoroughness. The glass lining of the drier avoids metallic contamination and resists product adherence, reducing clean-up losses and labour and improving heat transfer.

*

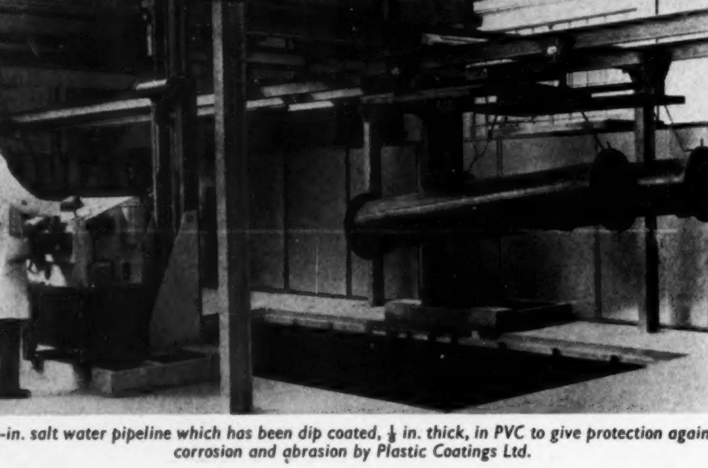
Plastic Coatings Ltd. will be exhibiting items of engineering plant that have been specialist corrosion proofed in polyethylene, nylon and PTFE.

*

Dexine Rubber Co. Ltd. will be exhibiting various pieces of plant including tank and pipe linings, rubber-lined diaphragm valves, a centrifugal pump and ebonite and *Dexoplas* pipes and fittings.

*

Tough Plastics Ltd. will demonstrate the *Tufplas* technique in industrial plastic fabrication. The large tank exhibited will give an indication



14-in. salt water pipeline which has been dip coated, 1/8 in. thick, in PVC to give protection against corrosion and abrasion by Plastic Coatings Ltd.

of the range of specially fabricated equipment available. Newly available moulded nylon and polypropylene laboratory taps, cocks and fittings will be seen.

Pipes

Rigid thermoplastic pipes and moulded fittings from $\frac{3}{8}$ to 6 in. nominal bore are to be shown by Durapipe & Fittings Ltd. Three different grades call for different methods of jointing which are being demonstrated at the exhibition. These include normal threading to B.S.P. specifications and heat welding and solvent welding.

*

John Gosheron & Co. Ltd. will be showing their range of corrosion-control tapes and how these materials are used by many industrial undertakings for extensive pipe protection work. The various applications of *Polyvil* PP heavy-duty PVC will be exhibited including the wrapping of butt-welded joints on large pipelines and the continuous wrapping of extended runs of smaller pipelines involving the use of the *Viper* pipe-wrapping machine.

*

On the stand of A.B.D.I.C. Ltd. there will be shown a range of plastic pipes, fittings, etc., from high-density polyethylene, *Kerlastic* and PVC. There will also be various other pieces of equipment such as a fume cupboard and a PVC sink.

*

Bristol Aeroplane Plastics Ltd. will show a pipe system of great strength, constructed from epoxy resin, reinforced with glass and acrylic fibres. In bores ranging from 4 to 15 in. this piping is said to be resistant both internally and externally to corrosion and chemical action without any protective sheathing.

*

A range of unplasticised PVC pipes and fittings will be shown by Chemidus Plastics Ltd. *Chemidus* 2000 unplasticised PVC has been developed to meet the requirements of the chemical industry.

*

Tecalemit Ltd. will be showing nylon tubing in two grades, flexible and semi-rigid, high-pressure nylon hose and injection mouldings of nylon and similar materials. The nylon hose consists of a core tube of nylon extruded to fine limits, a high-tenacity braiding and an outer sheath of flexible plastic tubing.

Large tank in fabricated plastic exhibited by Tough Plastics Ltd.

Valves

The exhibit of the Saunders Valve Co. Ltd. pays particular attention to remote-controlled valves. New developments include a rubber-lined non-return valve and a solid PTFE valve.

*

Meynell & Sons will be showing all types of *Rayon-Patent* glandless valves. These can be supplied either manually operated or remotely controlled with various body materials resistant to whatever lined fluid it is required to control.

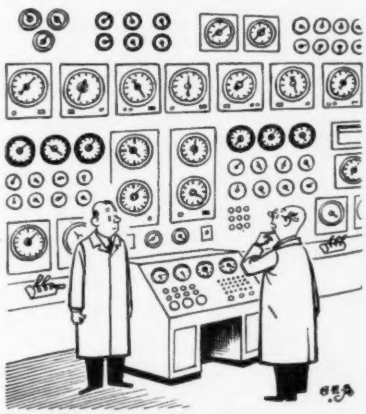
Services

A range of chemically resistant cements, jointing compounds and coatings will be on display at the stand of Corrosion Technical Services Ltd. The service offered by the company in corrosion engineering will be highlighted with particular emphasis on free advice, specification and drawings offered to architects and consulting engineers with regard to their corrosion problems, particularly for chemically resistant floor tiling and plant linings.

*

Prodorite Ltd. stand will show the service they offer to industry from design to the finished installation. This covers chemical engineering and acid-proof construction including tanks, floors, neutralising and effluent treatment schemes and fume extraction embodying a wide variety of corrosion-resisting mastics, compounds and a range of corrosion-resisting cements.

COMICAL ENGINEERING CORNER



"TIME? — LET ME SEE, THERE SHOULD BE A CLOCK HERE SOMEWHERE"

Chart for Dilution Calculations

By G. E. Mapstone,* Ph.D.

WHEN materials are being blended or diluted the use of percentages can be confusing to the inexperienced. For example, if the question is asked, 'How much water must be added to this slurry to increase the water content from 50 to 75%?' the almost instinctive answer is '25%', instead of 100% on the slurry. This can be easily shown by means of the following calculations.

Symbols used

A = Amount of diluent added as % of charge;
d_i = Initial diluent content of charge as %;
a_i = % of active material in charge;
d_f = Final diluent content of product as %;
a_f = % of active material in product.

Notes:

(i) $a_i + d_i = a_f + d_f = 100$ by definition.

(ii) The data can be used as % by weight or as % by volume (if no shrinkage occurs or if it can be neglected), but the same system must be used uniformly throughout any calculation.

Derivation

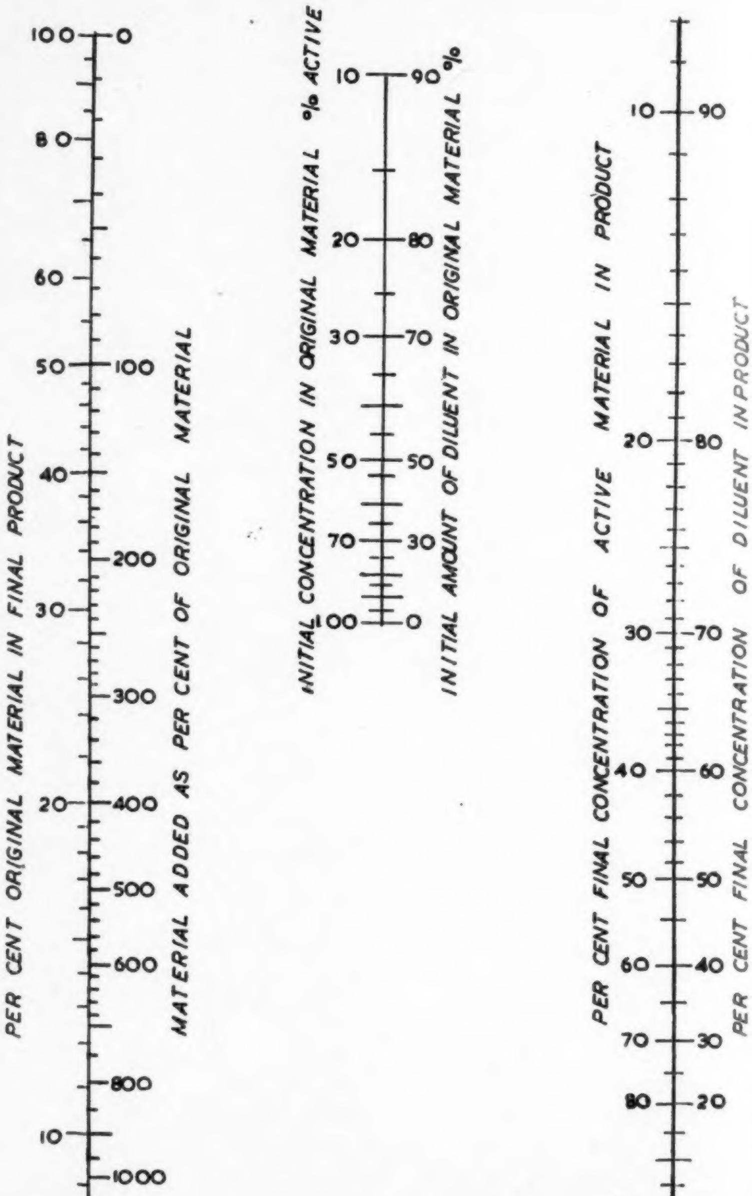
If we work on the basis of 100 lb. we have that the charge contains a_i lb. of active material and d_i lb. of diluent. In the final product we have d_f% of diluent and a_f% of active material. Therefore, the original a_i lb. of active material require a total of

$$\frac{a_i \cdot d_f}{a_f} \text{ lb.}$$

of diluent, of which only d_i is present in the charge. The amount of diluent that is required to be added, A, to the 100 lb. charge is:

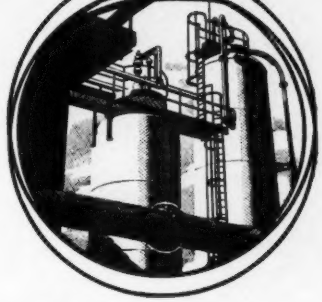
$$A = \frac{a_i \cdot d_f}{a_f} - d_i$$

(*Concluded on page* 518)



**Dermacult (S.A.) Pty. Ltd.*

Materials of Construction for Chemical Plant



COPPER

By S. Baker,* Ph.D., M.Sc., A.R.I.C.

This is the seventh article in our series on the 'Materials of Construction for Chemical Plant', which has included PVC, lead, nickel, stainless steel, graphite and polyolefines. One of the oldest metals known to man is copper and its use in the chemical industry dates back many centuries, as is attested by the historic spirit and essence stills, and brewing vats. Modern developments in copper and its alloys are reviewed in this article which discusses the importance of this group of metals to the present-day plant designer.

COPPER was one of the first metals to be used by man; one of the reasons for this is that it occurs in the metallic state in many parts of the world. It was early discovered that by hammering this native copper the metal could be made hard enough for making weapons and other tools.

The production of copper by smelting its ores seems to have taken place quite early in history, and this greatly increased the amount of copper available. Another early discovery was that by the addition of tin to copper an alloy was produced which was much harder and stronger than copper, but which could also, in certain cases, be hardened still further by hammering.

The thousands of copper and bronze articles, including weapons, ornaments, bells, statues and vessels of all kinds which exist today in museums throughout the world, testify not only to the usefulness of these metals in early civilisations but also to the high state of craftsmanship attained by these early workers. At the end of the 18th century Great Britain was the largest producer of copper in the world, with an output of about 10,000 tons p.a.

The opening up in the 19th century of the copper mines in North America, Chile and Australia to meet the demands of the new industrial age, received a tremendous impetus from the growth of the use of electricity in the later decades.

Early in the 20th century the extensive deposits in Central Africa were developed and these now contribute an important proportion of the 4 million tons of copper required annually by the world today.

The extensive use of copper and its alloys in chemical and related industries depends upon the combination of properties which they have to offer. They all have high resistance to corrosion, which is of paramount importance to the chemical engineer. Copper itself has moderate strength up to medium temperatures and high ductility while, by suitable alloying, materials are made available with a wide range of properties. Thus small additions of beryllium provide a metal with the strength of high-speed steels; tin, bronze and brass combine strength and ductility; tellurium in copper and lead in brass confer ease of machining; and nickel and aluminium additions produce alloys of high strength, with enhanced corrosion resistance in certain circumstances.

Grades of copper

Copper is available in a number of commercial grades of varying purity and the following British Standards refer to copper in its commercial unworked forms:

1035	Cathode copper
1036	Electrolytic tough pitch high-conductivity copper
1037	Fire-refined tough pitch high-conductivity copper
1038	99.85% Tough pitch copper
1039	99.75% Tough pitch copper
1040	99.50% Tough pitch copper
1172	Phosphorus deoxidised non-arsenical copper
1173	Tough pitch arsenical copper
1174	Phosphorus deoxidised arsenical copper
1861	Oxygen-free high-conductivity copper

The high-conductivity grades are primarily of interest to the electrical engineer and they are of high purity, the copper content being 99.90% minimum. The difference between 'electrolytic' and 'fire-refined' is one mainly of manufacturing method, the electrolytic process of refining being essential when precious metals are to be recovered from the refined copper.

'Tough-pitch' varieties contain a small amount of oxygen which is purposely present so as to obtain a casting with a level surface suitable for the further processes of rolling and drawing. The amount of oxygen varies between 0.025% up to, in some

*Copper Development Association.

cases, 0.10%. This quantity of oxygen has a negligible effect on the mechanical properties and the conductivity, but has, however, a marked influence on the behaviour of copper when it is heated to high temperatures in the presence of reducing gases such as hydrogen. The interaction of the hydrogen with the oxygen to form steam results in 'gassing' of the copper with severe reduction in its strength and ductility. The principal practical disadvantage of this reaction is that gas welding becomes a somewhat difficult operation because of the reducing gases in the oxy-acetylene flame. To overcome this disadvantage, deoxidised grades of copper are also available. Phosphorus is the usual element added to remove oxygen, and a small amount—less than 0.1%—generally remains in the copper. Even this quantity does, however, have a marked effect on the conductivity.

Arsenic in amounts from 0.3 to 0.5% may be added to both tough-pitch and deoxidised varieties as it improves slightly the mechanical properties and raises the annealing temperature by about 100°C.

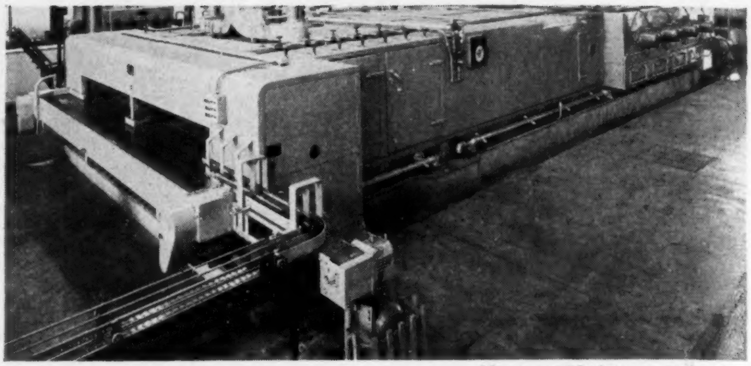
Oxygen-free high-conductivity is also available in which the presence of oxygen is avoided by preventing its absorption during refining and casting.

Mechanical properties

There is little variation in the mechanical properties of different varieties of copper and the values given in Table 1 can be taken as average for relatively thick strip or rod.

Copper in the cast state has a tensile strength of about 10 to 11 tons/sq.in. Rolling, forging or other forms of hot working modify the structure and raise its tensile strength. The same sequence is present in autogenous welding, where the weld metal is originally in the cast state, and hammering of the weld has to be carried out to develop its full strength.

Cold-working processes increase the tensile strength of copper while at the same time the ductility (as measured by the elongation) is decreased, as shown in Table 1. Therefore, if much cold work is to be carried out annealing becomes necessary. Though annealing takes place slowly at temperatures at a little over 100°C., this is far too slow for commercial operation, which is usually effected by heating the copper to 500° to 600°C. for up to half an hour. Neither the temperature nor the time are critical since grain growth is slow. The metal may be allowed to cool either in air or be



(Courtesy of S. Briggs and Co. Ltd.)

Copper-lined pasteuriser in a brewery.

quenched in water, the latter being more usual since this operation loosens oxide scale which has formed during annealing, and also allows further operations to be continued without delay.

At sub-zero temperatures the mechanical properties are improved.

Some idea of the behaviour at moderate temperatures can be gained from Table 2, which shows the creep strength of three grades of copper in wire form in the annealed condition.

The effect of arsenic in raising the strength at these temperatures is quite noticeable.

The thermal conductivity of normal high-conductivity copper is 0.74 B.Th.U./sq.ft./in./sec./°F. (0.92 c.g.s. units).

The conductivities, both thermal and electrical, are very susceptible to small amounts of other elements, particularly phosphorus and arsenic. In many cases this decrease is of little importance in the total heat transfer, since the controlling factors in most heat exchangers are the fluid films on each side of the metal. The smooth surfaces of the metal, combined with the absence of corrosion products, do, however, keep these films at a minimum so that a high overall heat-transfer rate is obtained.

Joining

A number of methods are available for jointing copper, such as welding, brazing, soldering and riveting. Plant which is to be exposed to corrosive conditions has nearly always been fusion welded since deoxidised copper was made available early in this century. Until recently oxyacetylene welding was the principal method adopted because metallic arc and carbon arc processes gave unsatisfactory results. In the last few years, however, arc welding in which the deposition of weld metal takes place surrounded by an inert-gas atmosphere has been rapidly growing in importance. This inert-gas shielded-arc process is probably destined to become the principal joining method for copper once the technique of its application is fully understood.

Fusion welding with thin sections can be carried out without a filler rod, but with thicker material filler

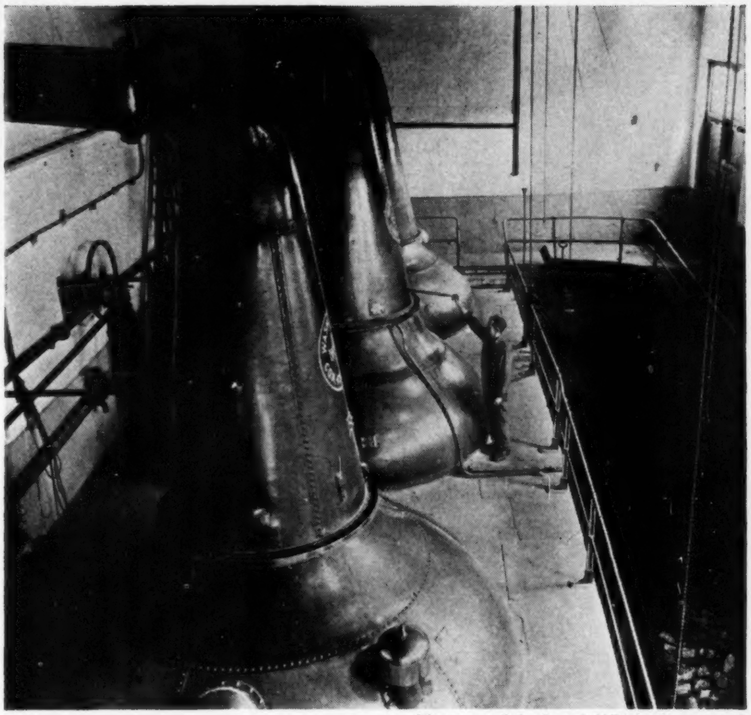
Table 1. Typical mechanical properties of copper

		Annealed	Cold worked hard
Limit of proportionality	Tons/sq.in.	1	12
0.1% Proof stress	Tons/sq.in.	4	21
Tensile strength	Tons/sq.in.	14	25*
Elongation, %		50 to 60	4
Diamond pyramid hardness		50	115

* Up to 30 tons for wire

Table 2. Creep strength of copper wire

Type of copper	Stress in p.s.i. for creep rate of 0.01%/1,000 hr. at 150°C.	205°C.	260°C.
Electrolytic tough-pitch annealed	2,950	1,300	350
Phosphorus deoxidised non-arsenical annealed	5,400	2,650	900
Phosphorus deoxidised arsenical annealed ..	8,400	5,200	2,600



(Courtesy of the Scotch Whisky Association)
Whisky stills.

rods as specified in B.S. 1077 should be used. These contain small additions of phosphorus and optional amounts of silver and silicon in order to ensure that the weld area is kept in a deoxidised condition. In applications where corrosion risks are virtually absent, other methods of joining such as bronze welding or brazing or silver soldering provide satisfactory joints with adequate strength. Ordinary soft solder is often used in assemblies which are not exposed to elevated temperatures or corrosive environments.

Corrosion resistance

The corrosion resistance of copper is of a high order in a wide variety of conditions and this property is often the determining factor in influencing its choice as a construction material for chemical plant.

Under ordinary outdoor atmospheric conditions copper tarnishes and slowly develops a green patina consisting mainly of basic copper sulphate, though basic chloride may predominate close to the sea. Some basic carbonate is also generally present. Once the green patina has formed it virtually prevents further attack by the atmosphere, and the protection can last for centuries. In rural or sheltered positions the attack by the atmosphere may be very slow and the green patina may never develop, while in sheltered industrial situations the patina may be masked by a layer of soot or dirt.

Water

In contact with waters which are not acid in character copper develops an oxidised coating which prevents it going into solution in the water, except perhaps for an initial short period while the coating is forming. Some waters, such as those derived from moorland areas or private wells may, however, be sufficiently acidic, so that the oxidised coating does not form, and small amounts of copper continue to pass into solution. This can cause green staining of sanitary equipment, sponges, etc., and if this becomes objectionable the water can be treated with lime or magnesia.

Most types of soil are without action on copper buried in them, but in made-up ground, cinders and certain acid soils, some further protection may be required such as wrapping with bituminous tape.

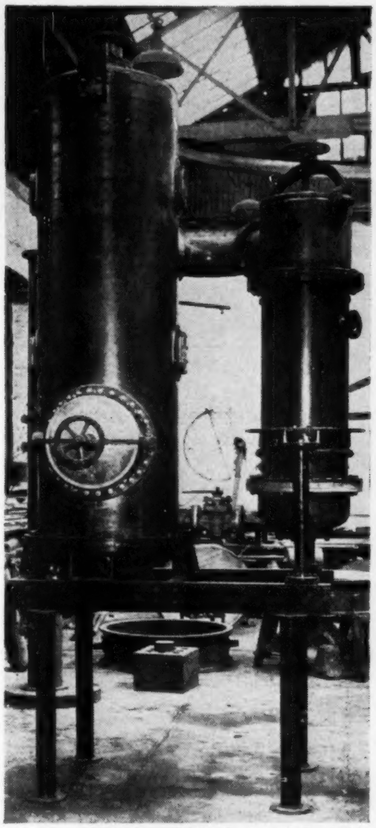
Acids and alkalis

Copper is resistant to attack by many acids, though the presence of air or other oxidising conditions can lower this resistance markedly. Thus sulphuric acid by itself when not too concentrated has virtually no effect on copper, but when air is also present, and particularly when the temperature is raised, attack is relatively rapid.

Nitric and hydrochloric acids, except in very dilute solutions, react vigorously with copper and its alloys.

Copper equipment is used in the manufacture of acetic acid although, if air is present, some corrosion may take place. Copper also offers very good resistance to a large number of organic acids such as formic, oxalic, and tannic.

Copper resists attack by caustic soda and potash solutions fairly well, but in manufacturing processes the higher resistance of nickel and its alloys is generally utilised.



(Courtesy of John Dore and Co. Ltd.)
Vacuum evaporator in copper.

Lime has no effect on copper. Ammonia has, however, a strongly corrosive action on copper and its alloys when moist or in solution.

Salts

Copper is resistant to attack in contact with a wide range of inorganic salts.

Table 3. Properties of some typical alloys

Material	% Composition			Annealed			Hard		
	Cu	*Zn*	*Other elements*	*Tensile strength, Tons/sq.in.*	*Elongation, % on 2 in.*	*Limit of proportionality, tons/sq.in.*	*Tensile strength, tons/sq.in.*	*Elongation, % on 2 in.*	*Limit of proportionality, tons/sq.in.*
H.C. Copper ..	99.90			14	50 to 60	1	25	4	12
Phosphor-deoxidised copper	99.85								
Cartridge brass (tube)	70	30	0.02 to 0.06 As	21	70	3.5	38	10	15
Admiralty brass (tube)	70	29	1Sn; 0.02 to 0.06As	22	70	4	38	10	15
Aluminium brass (tube)	76	22	2Al; 0.02 to 0.06As	24	70	4	40	8	16
Muntz metal (Hot-rolled plate)	60	40		24	40	4	—	—	—
Naval brass (Hot-rolled plate)	62	37	1Sn	25	40	5	—	—	—
High-tensile brass, medium strength	55 to 63	Rem	Max. 0.5Pb; 0.5Sn 3.0Mn; 5.0 Al 2.0 Ni; 0.5 to 2.5Fe	38 to 45	15 to 20	—	—	—	—
Phosphor bronze (tube)	94	6	0.1P	24	60		40	10	
Admiralty gunmetal (cast)	88	2	10Sn	16 to 22	12 to 20	—	—	—	—
Leaded gunmetal ..	85	5	5Sn; 5Pb	13 to 18	15 to 25	—	—	—	—
Aluminium bronze (tube)	Rem	—	4 to 7 Al. Up to 4Mn and/or Ni	25	70	4	50	4	20
Aluminium bronze (cast)	Rem	—	9.5Al. 4.5Fe; 5.5 Ni; up to 1.5 Mn	40 to 45	12 to 20	—	—	—	—
Cupro-nickel ..	70		30 Ni; up to 1.0Fe	23	45	4	42	5	25
Copper silicon ..	96		3Si; 1Sn, Zn or Mn	23	70	4	50	5	20

The presence of impurities or the liability of the salts, particularly the chlorides, to hydrolysis can often be the determining factors governing the suitability of copper as a constructional material.

Organic substances

Copper and its alloys are extensively used by the industries which prepare and use organic solvents. These include the manufacture of alcohols, chloroform, ether, acetone, turpentine and esters as well as the recovery of many of these liquids in processes where they are used as intermediates.

Copper alloys

Table 3 gives the composition and average properties of some typical copper alloys, chosen from the very large number which is available.

In general these alloys have corrosion resistance similar to copper, while the added elements provide higher strength and greater ease in founding and machining, though often with some loss of ductility.

The alloying elements most commonly used are zinc, tin, nickel, aluminium and lead, while others in less frequent use include silicon, beryllium, tellurium, manganese and iron. The alloys can be conveniently considered under the following headings:

(*a*) Brasses
(*b*) Tin bronzes and gunmetals
(*c*) Aluminium bronzes
(*d*) Copper-nickel alloys
(*e*) Copper-silicon alloys
(*f*) Miscellaneous

Aluminium bronze liquid channel for heat exchanger.

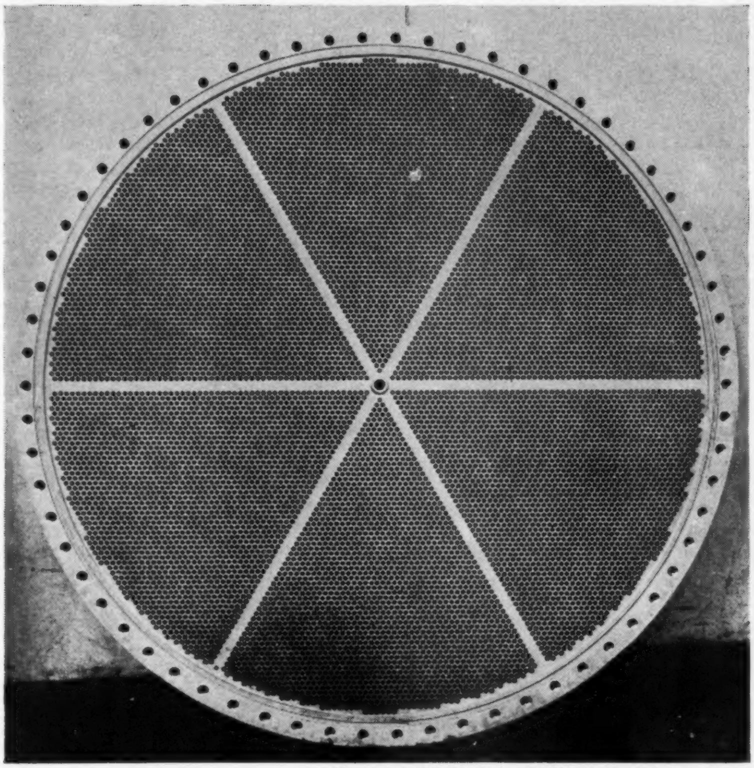
(Courtesy of T. M. Birkett, Billington and Newton Ltd.)

(a) Brasses

These are the most important copper alloys and include gilding metals, cartridge brass, Admiralty brass, Naval brass and high-tensile brasses, to name a few typical alloys in decreasing order of copper content. They are basically copper-zinc alloys in which the zinc content varies up to about 45%. As the zinc content increases so the strength and ductility until the latter reaches its maximum with 30% zinc (cartridge brass), providing an excellent cold-working alloy. The addition of 1% of tin provides somewhat improved corrosion resistance, and the resultant alloy is known as Admiralty brass; both this (70/29/1) and the 70/30 alloys are widely used for condenser and evaporator tubes.

Increasing use is being made of aluminium brass, of composition copper 76%, zinc 22% and aluminium 2%, because it has much better resistance to high speeds of cooling water in condensers. These three condenser tube alloys have traces of from 0.02 to 0.06% of arsenic added to them to prevent dezincification. This is a form of corrosion of which the result is the removal of zinc from the alloy, leaving a weak and porous deposit of copper.

When the zinc is increased to beyond about 37% the alloy becomes duplex in character; the strength continues to increase but the ductility is rapidly reduced. These alloys have, however, a wide plastic range at high temperatures, and are therefore very



(Courtesy of T. M. Birkett, Billington and Newton Ltd.)
High-tensile brass cast tube plate 5 ft. 7 in. diam., with 11,000 drilled holes.

suitable for hot-working processes such as extrusion, die casting, stamping and hot rolling. The latter process is used to provide some of the larger condenser plates which are common when copper-alloy tubes are used.

The addition of lead (0.5 to 3.5%) to brass improves machinability, but adversely affects the hot-working properties.

The addition of other elements such as aluminium, iron, manganese and silicon to the duplex brasses produces the class of alloys known as high-tensile brasses, or manganese bronzes as they are often misnamed.

While the brasses are extremely important in general engineering and for ancillary purposes in chemical works, they are not so resistant under many corrosive conditions as other copper alloys. The very valuable properties of the high-tensile brasses, for instance, cannot be utilised in many corrosive situations because of their liability to corrosion by dezincification, which cannot be prevented by additions of arsenic, as is the case with the 70/30 type of brass. Even without the addition of other elements, the possibility of dezincification becomes more remote the lower the proportion of zinc, and can generally be ignored when this is less than 15%.

(b) Tin bronzes and gunmetals

The corrosion resistance of these alloys can be considered as not inferior in any way to that of copper and in some applications superior, and they are extensively used in chemical plant construction, predominantly as castings.

When the tin content is less than about 8%, tin bronzes are very ductile and suitable for cold working and so are used for making tubes, for condensers and other purposes.

For cast products such as valves and fittings, gunmetals are used instead of the straight tin bronzes. One of the best known alloys is Admiralty gunmetal which contains 88% copper, 10% tin and 2% zinc.

However, other compositions which economise in tin without sacrifice of other properties are widely used, such as the 88/8/4. In order to facilitate machining, lead is a frequent addition, giving a range of leaded gunmetals, of which the best known is the 'eighty-five three fives' (85% copper, 5% each of tin, zinc and lead).

The gunmetals have excellent casting qualities, and are popular for valves, fittings and pump parts as well as reaction vessels.

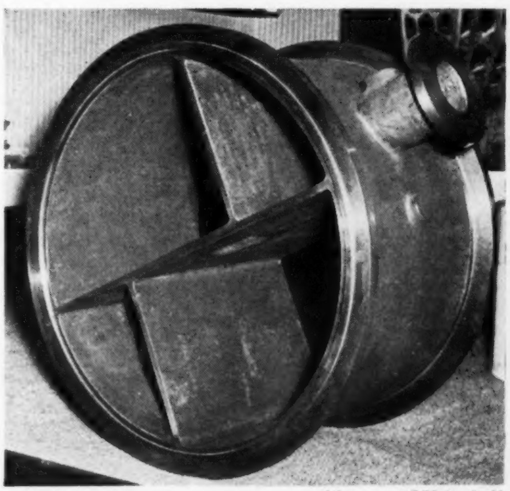
The strength and hardness of gunmetals may be increased by the addition of nickel, in amounts up to 5%.

(c) Aluminium bronzes

These alloys, owing to the invisible continuous film of aluminium oxide which forms on their surfaces, are highly resistant to oxidation and scaling, and for that reason are among the best copper alloys for service at moderately elevated temperatures. They also include some of the strongest of the copper alloys.

With aluminium contents in the range of 4 to 7% the alloy is homogeneous and suitable for cold rolling, and for manufacture into tubes and sheets, which are being increasingly

Copper vessel of ⅜ in. plate 22 ft. long × 14 ft. 6 in. diam.



(Courtesy of Blairs Ltd.)

used for heat exchangers. These alloys often contain small additions of manganese and/or nickel.

The duplex aluminium bronzes usually contain 9 to 10% of aluminium, together with iron and nickel, the alloy containing 5% of each of these having a strength of over 45 tons/sq.in. at ordinary temperatures and 24 tons/sq.in. at 400°C. The duplex alloys are being increasingly adopted for pumps, fittings and other cast parts.

(d) Copper-nickel alloys

Copper and nickel form a homogeneous solid solution throughout the complete range of composition. The alloys containing 20 and 30% of nickel, the latter with the addition of 1% of iron, are extensively used for condensers, because of their resistance to corrosion allied to their strength and ductility. They are particularly valuable with condensing waters which may be polluted, a condition which happens more frequently nowadays when the new oil refineries have to draw their cooling water from the sea or from tidal waters.

The addition of zinc to copper-nickel alloys produces the nickel silvers. The nickel varies from 10 to 30%, and the zinc from about 13 to 27%. They are not relied on much for chemical work, though they play an important part in domestic and decorative applications.

Many other alloys of copper and nickel are widely used, as for example the resistance alloys (55/60 copper, 45/50 nickel). *Monel* is a strong, highly corrosion-resistant nickel alloy which contains about 30% copper. Its properties and uses have been described in the article on nickel (CHEMICAL & PROCESS ENGINEERING, 1960, **41**, p. 295).

(e) Copper-silicon alloys

Copper-silicon alloys may contain up to 5% of silicon with smaller additions of manganese and iron. The alloys are much stronger than copper, though they are still very ductile and therefore are suitable for coppersmithing operations. The silicon lowers the conductivity greatly, and this enables the metal to be readily welded either by oxy-acetylene flame or by electric methods, the silicon itself acting as a deoxidiser. These alloys are also suitable for castings, and are widely used for their corrosion-resisting properties.

(f) Miscellaneous alloys

Many other alloys of copper are of importance in the engineering industry, but as they have little application in chemical and related plant, only a passing reference to them need be made. Among these are: beryllium copper—containing about 2% beryllium—which produces the strongest of the copper alloys and is widely used for springs and similar instrument parts; tellurium copper—containing 0.5% tellurium—which has extremely good machinability combined with high conductivity; and chromium copper—with up to 1% chromium—which has much greater strength than copper, with only small sacrifice of conductivity.

The material of construction for chemical plant which will be discussed in next month's issue of CHEMICAL & PROCESS ENGINEERING will be

TIMBER

Applications

Copper and its alloys have a long history of service to the chemical industry and, until the present century, it was almost the only practical alternative metal to iron and steel for most purposes. Thus they are the traditional metals for the brewing and distilled spirit industries. They find extensive applications also in such processes as petroleum refining, sugar refining, jam and confectionery production, the manufacture and recovery of alcohols, esters and other organic solvents, and particularly in all forms of heat-transfer apparatus, such as evaporators, stills, condensers and heat exchangers.

Copper itself is nearly always used in the wrought form as sheet or tube, while the fittings such as valves, pumps and other cast parts are manufactured from one of the copper alloys. The latter, when joined to copper, do not give rise to galvanic corrosion, except under severe corrosive conditions.

Chart for Dilution Calculations

(*Concluded from page* 512)

Since $a_i = 100 - d_i$ and $a_f = 100 - d_f$ we can rewrite this relationship in terms of the diluent concentrations as

$$A = \frac{100 - d_i}{100 - d_f} - d_i$$

or, after rearrangement, in terms of the active matter concentrations as:

$$\frac{100 + A}{A} = \frac{a_i}{a_f}$$

These relationships are most conveniently solved by means of the accompanying nomograph, the use of which is best illustrated by means of some examples.

Example 1

Q. A paste contains 30% of water. How much water must be added to give a final water concentration of 80%?

A. Use a straight edge to connect 30% initial diluent (water) concentration on the right-hand scale of the centre line with 80% final diluent (water) concentration on the right-hand scale on the right-hand line and extend to cut the left-hand line. The point of intersection is 250 on the right-hand scale; therefore the water addition required is 250% on the cream of 2½ lb. of water/lb. of cream.

Example 2

Q. A detergent material containing 55% active matter is to be used in a shampoo. What concentration of this material is required to give an active matter concentration of 20% in the shampoo?

A. Use a straight edge to connect 55% initial active matter concentration on the left-hand scale of the centre line with 20% final active matter concentration on the left-hand scale of the right-hand line and extend to cut the left-hand line. The point of intersection is 36.4 on the left-hand scale; therefore 36.4% of the detergent product is required or 36.4 lb. in 100 lb. of product.

Example 3

Q. Three parts of water are added to one part of an emulsion containing 80% oils. What is the water content of the product?

A. Three parts of water added to one part of emulsion is an addition of 300%. Use a straight edge to connect 300% material added on the right-hand scale of the left-hand line with 80% initial active matter concentration on the left-hand scale of the centre line and extend to cut the right-hand line. The point of intersection is 20 on the right-hand scale. The final water content of the emulsion is therefore 80%.

What's New

in Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

Purifying and drying hydrogen

To meet the demand for a self-contained unit, combining the features of the *Deoxo* catalytic purifier, for removing oxygen from gases, with those of an automatically operated drying unit containing *Linde* molecular sieve, Engelhard Industries Ltd. have produced the *Deoxo Puridryer.*

This unit, having a maximum capacity of 100 s.c.f.h., will purify normal commercial-grade hydrogen to give a gas with an oxygen content of less than 1 p.p.m. By use of the molecular sieve as the drying agent it achieves a dewpoint as low as −100°F. (−73°C.), which enables the gas to be fed directly to a furnace.

The unit may also be used with other gases such as nitrogen, argon, neon and saturated hydrocarbons, providing that two volumes of hydrogen are present in the gas to react with each volume of oxygen impurity to be removed. **CPE 1577**

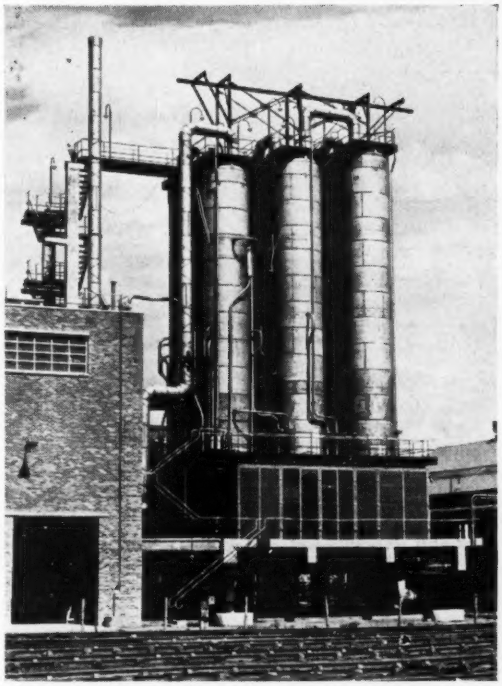
Water demineralisation

The portable *Deminrolit* made by the Permutit Co. Ltd. is claimed to convert up to 12 gal./hr. of clean cold water into demineralised water having a conductivity of less than 1.0 reciprocal Megohm/cm. The quality of water produced by the unit is claimed to conform to the 'purified water' standard of the British Pharmacopœia, 1958.

The instrument is a mixed-bed ion exchanger. The ion-exchange materials used are *Zeo-Karb* 225 and *De-Acidite FF.*

It is designed for regeneration on the spot. A conductivity tester is fitted which continuously monitors treated water quality. Constructed as a free-standing, non-corrodible unit, it is said to be suitable for both workshop and laboratory conditions. The unit is connected by flexible hose.

CPE 1578



A high-level lifting runway is shown mounted above a battery of absorption towers at a new plant in Scotland.

Nitric acid plant handling installation

A handling installation, which involves a high-level lifting runway for use at a new nitric acid plant in Scotland, has been completed by British Electrical Repairs Ltd.

In the final stages of weak nitric acid production, there are six stainless-steel cylindrical absorption towers, the tops of which are about 100 ft. high. The towers, in three groups of two, are surmounted by platforms at three different levels and each has an opening on top for subsequent coupling to feeder trunking and for the initial purpose of allowing access for the packing of each tower with thousands of ceramic rings, each about the size of a teacup. The rings would require to be raised in bulk up the outside of the towers and lowered in lesser quantities into the towers through the ports.

Loading of the towers manually was considered uneconomic and hazardous and, after consideration of various other methods, a scheme was prepared whereby a 46-ft.-long runway supported by three goalpost structures was landed on the platforms 100 ft. up. As there were three different port opening positions, the goalpost bases were seated on double-channel transverse runners so that, as each group of towers was filled, the whole runway structure could be moved horizontally across to the next set of ports.

The runway structure was erected in two parts at ground level and each part was raised and sited on the plat-

forms by means of a 120-ft. jib mobile crane. A travelling electric hoist unit traversed the runway, raising bulk loads of ceramic rings weighing ½ ton to platform level, and lowering smaller quantities in 'kitbag'-shaped containers into the towers. **CPE 1579**

Flowmeter calibration

On chemical plants and refineries where large numbers of variable-area flowmeters are in constant use it is useful to have facilities on the site for calibrating and checking these instruments. It is with this in mind that Fischer & Porter Ltd. offer a calibration unit which may be used for flowmeter calibrations up to a maximum flow rate of 60 Imp.gal./min. (water).

The stand is about 9 ft. high and requires floor space of 8 × 4 ft. The principle of the unit is that water is passed through the instrument being calibrated at a manually controlled constant rate; the water is then collected in one of the calibrated measuring vessels. The whole operation is timed and the reading of the measuring vessels is taken from the appropriate calibrated sight glass.

There are three measuring vessels incorporated in the unit. The low has a capacity of 1 gal. and is calibrated in $\frac{1}{10}$-gal. intervals, the medium has an 8-gal. capacity and is calibrated in 1-gal. intervals and the high has a capacity of 60 gal. and is calibrated in 4-gal. intervals. **CPE 1580**

Cobalt-60 radiography

Cobalt-60 sources for radiography with the high specific activity of 10 curies/g. are now being prepared by Atomic Energy of Canada Ltd. and are available in the U.K. through the industrial division of Watson & Sons (Electro-Medical) Ltd.

These sources are made up from nickel-plated, cylindrical pellets of cobalt measuring 1 × 1 mm., which are double sealed in welded, stainless-steel capsules.

The sources prepared from this high-specific-activity material have extremely small physical dimensions for their output. This enables sharper radiographs to be made or, alternatively, shorter source to film distance to be used, thus considerably reducing exposure times. Small dimensions give a lower degree of the wasteful self-absorption within the source.

A range of standard sources made up from 100 curies/g. material is now available. **CPE 1581**

Pallet-levelling press

Fuller use of existing storage capacity for bagged chemicals is said to be made possible by a hydraulically operated pallet-levelling press offered by Heenan & Froude Ltd.

One of these presses, installed in the warehouse of a chemical company, has increased the existing storage capacity by about 50%. The company produces several hundred tons of chemical powders each day and despatches most of its output in 56-lb. paper sacks which, after filling, are stacked 40 to a pallet and shifted to and from their storage quarters by means of fork-lift trucks.

The loaded pallets could only be stacked to a height of two pallets and, as production increased, the existing warehouse facilities were becoming inadequate.

A pallet, stacked with forty 56-lb. paper sacks of chemicals undergoing compression in the new hydraulic press. In the centre is a similar pallet previously dealt with.

The press which has been designed to minimise this problem does so by taking a fully loaded pallet, applying an even spread of pressure to the top of the pallet's load and reducing the overall height from about 4 ft. 2 in. to an average of 3 ft. 1 in. This compression, in addition to reducing the overall height of the loaded pallet by 26%, also ensures an improvement in the stability of the stack, a combination of factors which makes it possible to store the pallets in tiers of three instead of two. Subject only to the height of the storage building and the maximum operating height of the fork-lift truck, it would be possible to stack the pallets in tiers of four. **CPE 1582**

Molecular distillation equipment

George Scott & Son (London) Ltd. have entered into an agreement with Arthur F. Smith, U.S.A., for the manufacture and sale of molecular distillation equipment of commercial size, with heating surfaces from 4½ sq. ft. upwards.

The *Scott-Smith* molecular still, which operates at high vacuum with the lowest possible heating temperature and short contact time, is said to be suitable for distillation, purification and deodorising of heat-sensitive materials of relatively high molecular weight, like vitamins, hormones, sterols, plasticisers and so on. **CPE 1583**

Hard water in paint

The build-up of lime deposits mixed with paint on water-wash booth flow sheets is a frequent occurrence, particularly in hard-water areas. An important problem which arises is that the deposits dull the reflective surface of the flow sheets, thereby lessening the degree of light in the booth. While the deposits can be cleaned off with phosphoric acid and abrasives, this action results in a further dulling of the surface.

To overcome this problem, Aerostyle Ltd. has developed a hard-water-grade additive. The use of this compound in the water is said to prevent effectively any build-up of deposits, and thus maintain the finish of the flow sheets. Hard-water-grade additive is introduced in the proportion of about 6 to 8 lb./100 gal. of water, according to hardness and acidity. **CPE 1584**

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Protective clothes

The above are five of the models which appeared in the protective and industrial clothing parade at the Factory Equipment Exhibition in Manchester.

Fig. 1 is a special type of clothing supplied to the U.K.A.E.A. The neoprene-coated crash suit is by P. Frankenstein & Sons (Manchester) Ltd. and was exhibited on behalf of I.C.I. Ltd. **CPE 1585**

Fig. 2 is a heat-reflective two-piece suit by Siebe Gorman & Co. Ltd. for use in intense heat such as in furnaces, brick ovens and paint drying tunnels. The outer garments are made from aluminised asbestos cloth (the jacket employing the fulcrum principle) and the inner insulating lining is made from four layers of different materials. **CPE 1586**

Fig. 3 is a chemical-resistant boiler suit in nylon-supported PVC material by Northide Ltd. The anti-splash cap and visor, PVC gauntlets and acid-resistant boots by Dunlop complete the outfit which is recommended for use when handling dangerous chemicals. **CPE 1588**

Fig. 4 is a one-piece suit worn by men working in particularly dangerous conditions who must be protected from liquid splash. The garment is by R.F.D. Ltd. and was exhibited by I.C.I. Ltd. **CPE 1589**

Fig. 5 is a PVC-coated rayon combination suit by Siebe Gorman. It is for wear by chemical workers, giving protection against acids, alkalis, oils, water, etc. It is ventilated at the back to prevent condensation. It has adjustable straps at wrist and ankles so that sleeves and legs may be drawn tightly over gloves and boots. A hood (not shown) gives protection to head and neck. **CPE 1590**

Metallised PVC

A range of metallised materials is offered by E. S. & A. Robinson Ltd. The rolls available include non-toxic, unplasticised PVC films in calipers ranging from 0.001 to 0.020 in., the heavier calipers being suitable for vacuum-formed trays and packs; cellulose acetate film up to 0.0075 in. for boxes or for box lids and edges; cellulose acetate (0.001 in.) for laminating to paper or board for labels, swing tickets and general display and packaging work; cellulosic films which can be coated on the unmetallised side with heat seal lacquer for use as wrappers; and various polyester and polyamide films. **CPE 1587**

Magnetic valves

A range of magnetic valves for high-vacuum use which offers a wide range of optional features to suit the growing need for automatic control of vacuum apparatus is offered by N.G.N. Electrical Ltd.

Fill in and post the reply-paid card for details of any items in these pages, making sure to quote the correct 'CPE' reference number.

Sealing is between a *Nygon* (vacuum rubber) pad and a brass or stainless-steel cone seating. The valves are designed to operate against 15 p.s.i. pressure difference across the seating.

The standard $\frac{1}{2}$- and 1-in. types may be mounted either vertically or inverted. Larger types may be supplied either for vertical or for inverted mounting. Horizontal operation can be arranged for any size of valve.

Changeover, make or break contacts which operate when the valve is energised, may be fitted in order to operate interlocking circuits. The action of these contacts is controlled magnetically, but due to the design of the magnetic circuit the contacts may also be considered as mechanically interlocked with the valve mechanism. **CPE 1591**

High-vacuum gauge

A high-vacuum gauge, either portable or panel mounted, for production work and general laboratory use is offered by the Pulsometer Engineering Co. Ltd. This is a Penning-type cold-cathode ionisation gauge which has a range from 10^{-3} to 10^{-6} Torr. The construction is a ring anode with two plate cathodes, one on either side, sealed in a glass bulb connected to the vacuum system. A permanent magnet produces a magnetic field directed along the axis of the electrodes.

The gauge head is normally supplied enclosed in a metal case together with the magnet. Connection of the gauge head to the vacuum system is through a $\frac{1}{2}$-in. vacuum union and to the control unit by a 4-ft.-length of high-voltage cable. **CPE 1592**

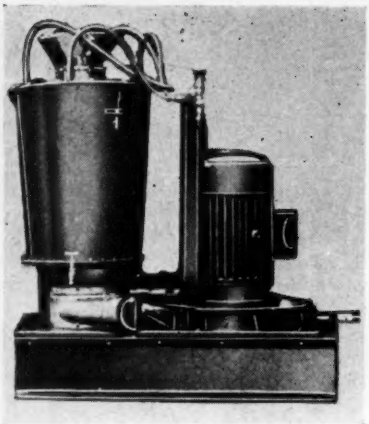
Thermal insulation powder

A powder which is claimed to provide buried heating pipes with thermal insulation and protection from corrosion is *Protexulate*, offered by Croxton & Garry Ltd.

It is said to be waterproof and that infiltration of moisture—even when the ground is saturated with water—does not occur, owing to its surface tension. Its free-flowing condition is maintained indefinitely.

It is poured direct from the bags into the trench covering the pipeline to a depth based on the dimensions of the pipes. The empty multi-ply paper bags are then placed over the powder and the trench filled in with earth.

CPE 1593



Milling and grinding machine.

'Protexulate' being poured direct from bags into the trench covering the pipeline to a depth based on the dimensions of the pipes.

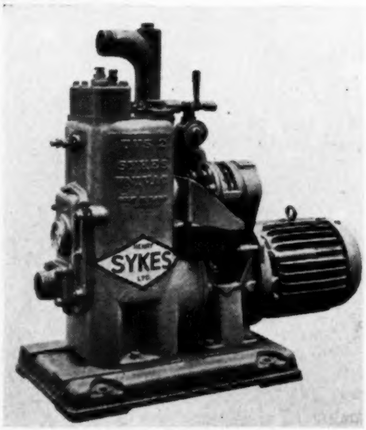
Ultrasonic cleaners

Recent additions to the range of ultrasonic cleaners available in the U.K. from Headland Engineering Development Ltd. are the American *DiSONtegrator* series, the smallest of which is the *System* 40, which has a tank capacity of ½ gal. (U.S.).

The generator is operated by a simple push/pull frequency control. The operating frequency of this unit, and also the 1½-gal. (U.S.) *System* 80, is 90 kc/s. The larger units which are available operate at 40 kc/s.

The tanks are manufactured from deep-drawn stainless steel. A choice of seven colours is available for the finish of the generator and tank case. Extra tanks and change-over switches are also obtainable if more than one solvent or cleaning operation is necessary.

CPE 1594



Self-priming pump.

Grinding mill

A grinding mill is offered by Russell Constructions Ltd. By generating vortices of air at extremely high velocities and causing their paths to intersect, the particles of material are made to bombard each other, thus bringing about a more rapid and complete disintegration, particularly of difficult products such as those of a fibrous nature.

The mill chamber takes the form of a hollow, steel cylinder mounted vertically (on a rigid base) having a diameter of 13¼ in. and a height of 18 to 24 in. A rotatable shaft is disposed co-axially within the mill chamber and mounted rigidly upon this shaft is a series of paddles. There is a clearance of $\frac{1}{16}$ to $\frac{1}{8}$ in. between the leading edges of the paddle blades and the internal wall of the mill chamber, which has a serrated surface. The paddle blades are disposed at intervals of 2¾ in. at their tips. The top closure of the mill chamber carries the shaft bearing and the delivery outlet and also houses an expeller fan mounted on the shaft.

Materials such as sugar, chalk, etc., can be reduced to particle size of all less than 50 microns (about 300 mesh) at the rate of 400 to 600 lb./hr.

CPE 1595

Centrifugal pump

An electrically operated 2-in. *Univac* self-priming centrifugal pump, offered by Henry Sykes Ltd., has a capacity of 6,500 gal./hr., when operating on a suction lift of 10 ft. and a nominal head. At nominal lift and a total head of 20 ft., the output is 8,000 gal./hr. The pump will pass solids of up to 1 in. diam. and will pump slurries of up to 60% solids content. On a 10-ft. suction it will prime in 12 sec., whilst on a 28-ft. suction the priming time is 65 sec.

The pump and impeller have been designed to handle sludges and pulps containing appreciable solids in addition to duties where only clear water or other liquids are involved. The pump castings are those of close-grained cast iron, as are the casing wearing plates and the impeller. The shaft is of mild steel with renewable sleeves and is, in effect, the extension of the motor shaft. The unit is 3 ft. long and 1 ft. 6 in. wide. The height is 3 ft. and the weight 480 lb. net.

CPE 1596

Personal Paragraphs

★ **Mr. M. J. Verey** has resigned from the board of Dewrance & Co. Ltd. and **Sir Donald Perrott,** K.B.E., has been appointed director and deputy chairman.

★ **Mr. E. J. Granger** and **Mr. J. W. Reynolds** have been appointed directors of John Bass Ltd.

★ **Sir Willis Jackson,** F.R.S., director of research and education of Associated Electrical Industries (Manchester) Ltd., is to return to academic life as professor of electrical engineering at Imperial College, University of London. Sir Willis, who is a former apprentice of the old Metropolitan-Vickers Electrical Co., now A.E.I. (Manchester) Ltd., resigned his chair at Imperial College some seven years ago to become director of research and education of the Manchester company.

★ Senior appointments at the Atomic Energy Research Establishment, Harwell, which took effect from the beginning of September are: **Dr. F. A. Vick,** O.B.E., deputy director of the establishment, became director; **Dr. R. Spence,** F.R.S., chief chemist, became deputy director; and **Mr. L. Grainger,** head of the metallurgy division, has been appointed assistant director with special responsibilities for applied research.

★ At the annual general meeting of the Plant Lining Group of the Federation of British Rubber and Allied Manufacturers **Mr. A. E. Allcock** of the Dunlop Rubber Co. Ltd. was elected chairman for 1960-61 and **Mr. T. H. Brooke,** managing director of Redferns (Bredbury) Ltd., was elected vice-chairman.

★ **Mr. A. Stephens** has rejoined Honeywell Controls Ltd. as senior flow engineer at the company's Greenford head office.

★ **Mr. G. C. Roberts** has been appointed director of Fairey Engineering Ltd. He was till recently managing director of Britvic Ltd. and its subsidiary companies and a director of Vine Products Ltd. He retains his chairmanship of E. & H. P. Smith Ltd.

★ **Mr. P. D. Scott** and **Mr. J. L. Smart** have been appointed vice-presidents of Dow Chemical of Canada Ltd.

★ Changes have taken place on the board of Howards of Ilford Ltd. **Mr. J. A. E. Howard** has become chairman, **Mr. E. W. M. Fawcett** and **Mr. H. P. P. Hodgkins** have become joint managing directors, and **Mr. W. A. Levick** and **Mr. R. C. Patrick** have become directors.

★ **Mr. C. J. Grayston** has been appointed as group research director of the recently opened research and development centre at Leven of the Balfour Group of Companies. He will have overall control of all sections of the enterprise.

★ **Mr. W. M. H. Stevens** has been appointed deputy chairman and joint managing director of Firth Cleveland Pumps Ltd. He was formerly the technical director of Bowser International Ltd. **Mr. R. W. Hill** continues as joint managing director and will control sales activities from the group headquarters in London.

★ **Mr. M. W. Vincent,** since 1955 head of the process laboratories of Sharples Centrifuges Ltd., has been appointed technical sales manager of Blaw Knox Chemical Engineering Co. Ltd.

★ **Mr. G. Smith** has been appointed as commercial executive of the electronic and equipment group of Plessey Co. Ltd. He was, until recently, general manager of the telecommunications division of the company.

★ **Mr. P. R. Keep** has been appointed manager of applications engineering at Atomics International, a division of North American Aviation Inc. He replaces **Dr. R. L. Loftness** who became commercial director of Dynatom, the company's new French affiliate.

★ **Mr. A. S. Paice** has been appointed export co-ordinator of Square Ltd. Until this appointment he was the company's Midlands area manager.

★ **Dr. R. H. Griffith,** director of research at the Gas Council's London research station, retired from his post at the end of August. He joined the research laboratory of the Gas Light & Coke Co. in 1925 from Magdalen College, Oxford.

★ **Dr. P. H. Calderbank** has been appointed to the chair of chemical technology in the University of Edinburgh in succession to **Prof. K. G. Denbigh,** who was appointed Professor of Chemical Engineering Science at the Imperial College of Science and Technology, London. The chair will be held concurrently with the headship of the chemical engineering department of the Heriot-Watt College. Dr. Calderbank has been Professor of Chemical Engineering in the University of Toronto and was head of the chemical engineering section at the Warren Spring Laboratory.

Mr. C. J. Grayston.

Mr. G. Smith.

Mr. P. R. Keep.

Mr. A. S. Paice.

★ Two new directors have been appointed to the board of the alkali division of I.C.I. Ltd. on the merger of the division and the company's salt division on January 1. **Mr. E. H. Sale,** who has been managing director of the salt division, will become a joint managing director and **Mr. E. K. Willing Denton,** commercial director of the salt division, will become a director of the alkali division.

New Books

Applied Organic Chemistry. By E. Kilner and D. M. Samuel. Macdonald & Evans Ltd., 1960. Pp. 500, illustrated. 50s. net.

This book contains 24 chapters dealing in the main with manufacture and use of heavy and fine organic chemicals.

As a supplement to existing textbooks on organic chemistry, intended to emphasise the industrial aspect, it perhaps falls rather short of its final object, but nevertheless a good deal of the subject matter will be of considerable value to the student of modern chemistry—particularly those undergoing industrial training as part of their curriculum.

In the early chapters the descriptive work on petroleum and the related industries opens up a new vista in what has too often become a closed book to the student of organic chemistry. Petrochemicals should have been given much more space, as the demand for knowledge of these is now considerable. Halogen derivatives tend to be catalogued in small paragraphs with insufficient detail—no mention is made of vinyl bromide and its important applications.

There are many important omissions, *e.g.* production of perchloroethylene by gas-phase chlorination of light hydrocarbons at 500° to 650°, and production of typical organo fluorine compounds—now becoming increasingly important—*e.g. Fluothane.*

One would also like to have seen more space devoted to the terpene alcohols with some reference to new developments in the synthetic field.

Amongst the aliphatic alcohols, glycerol deserves more than a paragraph, and its wide application merits as much space at least as pentaerythritol.

The acids and their derivatives are well described and the industrial processes for the derivatives are given in reasonable detail.

In Chapters 10, 11 and 12 an attempt is made to conclude the aliphatic section by description of protein products, oils, fats, waxes, carbohydrates, etc. The authors rather boldly define fats as glyceryl esters, when in point of fact all such are mixtures of simple and mixed glycerides, highly complex, but having constitution following certain natural laws. The paragraph on analysis of fats is most misleading—acid, saponification, iodine and Reichert Meissel values being only a fraction of modern technique in this field. The layout here is also rather confusing; it would have been much better to have first classified fats and oils, including drying oils, and then given some up-to-date methods of expeller extraction and details of refining processes.

Soap-making and fatty-acid production would follow, and in this connection some space should be devoted to production of long-chain fatty acids. Thus the section on drying oils might well be transferred to the first section on oils and fats and some information on the manufacture of polymerised oils would have been welcome. The brief references to paints, varnishes and lacquers might well be eliminated in favour of more information on synthetic waxes—their nature, their production and the technique of analytical procedure. Detergents might have been dealt with in a chapter by themselves.

In the second part of the book, the authors have adopted the conventional separation of aliphatic and aromatic compounds of industrial importance, and generally the industrial aspects—including manufacture and application—are well detailed.

High polymers including addition and condensation polymers are probably fitted in conveniently towards the end, being derived from aliphatic as well as aromatic groupings, and the authors in 50 pages provide a valuable summary of plastics materials, adhesives, surface coatings, etc. Possibly paints, synthetic resin emulsion paints, etc., described in Chapter 11 could have been conveniently included here—even if not all truly polymeric.

The chapter on colour, dyes, textile printing, etc., is thorough and up to date; advances in phthalocyanine pigment technology for example and their importance is clearly recognised; in the anthraquinone dyes, the newer blue wool dyes, brighter in shade and of better fastness, are given some prominence. It would have materially helped the student, however, if still more stress could have been laid on those dyes recently produced by improved syntheses and some indication given of their particular value. Few students may turn to the 'Reports on Progress of Applied Chemistry' and the authors would render a service if references from these reports were more widely quoted.

Finally, it is a pleasure to read a book of this type on applied organic chemistry and Messrs. Kilner and Samuel are to be congratulated on their pioneer effort. The text provides a valuable link between study of fundamental organic chemistry and the wide and ever-increasing accumulation of knowledge in the applied field. The diploma in technology student should read this book and will gain much from the factual knowledge of important processes so often omitted from the more academic texts.

J. H. Skellon,
Head of Department of Chemistry,
Brunel College of Technology.

Fundamentals of Chemical Engineering Operations. By M. G. Larian. Constable & Co. Ltd., 1960.

The author is Professor of Chemical Engineering at Michigan State University and has set out to produce a practical teaching book and it is fair to say that he has succeeded very well in this purpose. All through the text he attempts to start from the fundamental principles of the particular process concerned and only describe industrial plant for carrying it out in so far as it illustrates the fundamental principles. The usual American system of providing examples within a chapter where the solution is given, and also a set of questions at the end of the chapter is followed. This tends to break up the natural flow of the material, but is obviously useful in teaching.

The book is divided into three parts, the first part, general principles, deals with units and dimensions, flow of fluids, heat transfer, evaporation, mass transfer, phase contactors, and simultaneous heat and mass transfer. As is usual in chemical engineering textbooks, heat transfer by radiation is dealt with rather briefly because it is not so important in most of the equipment concerned in what one might call classical chemical engineering. The second main section deals with separation of mixtures by interphase mass-transfer operations, that is, drying, distillation, liquid-liquid extraction, solid-liquid extraction and gas adsorption. In this section, as in the last one, there is bound to be more description of practical apparatus than in the first section, and a tendency to illustrate this by a few arrows showing what happens inside it rather than by fundamental differential equations. The third section occupies only 100

pages and deals with the mechanical separation of heterogeneous mixtures, that is, gravitational centrifugal methods and filtration.

It is surely significant that in a complete book dealing with the fundamentals of chemical engineering operations, there does not appear to be any mention of a chemical reaction from beginning to end.

M. W. THRING,
Professor of Fuel Technology and
Chemical Engineering,
University of Sheffield.

Hyperonen und K-Mesonen (Monographien der Experimentellen und Theoretischen Physik, Herausgegeben von Franz X. Eder). By M. A. Markow. Veb Deutscher Verlag der Wissenschaften, Berlin, 1960.

One of the most exciting developments in the last decade or so has been the discovery of a number of new particles which appear to have as much claim to be called fundamental as those long-established building bricks of matter, the proton, the neutron and the electron. There are now three different kinds (and perhaps a fourth one) of mesons, particles of mass intermediate between proton and electron, and six different kinds of hyperons which are substantially heavier than neutrons, and most of these new particles have distinct antiparticles as well. About half of them behave so oddly that they have become known as 'strange particles'. Since 1955 the number of different particles appears to have become fairly stabilised and there are, in fact, fewer than were thought to exist 10 years ago. But the detailed behaviour of the various reactions by which they can be produced is still being actively explored, and so are the various ways in which they spontaneously transform themselves — sometimes through several intermediate steps—into stable particles. Even less is known, at present, about the forces which act between them when they come close together, and practically nothing about the reasons why such particles should exist at all; though most physicists feel that one day some subtle scheme will be discovered into which all these entities fit in a consistent and logical manner.

Clearly it is very difficult to write a book on a subject which is still in such rapid development and still has so many loose ends. The book under review is one of the few that have so far been written. It is based on a number of lectures which the distinguished Soviet physicist Prof. M. A. Markow gave early in 1957 in Moscow University and some other lectures which he gave elsewhere.

In the three years that have passed the subject has developed considerably and the author has attempted to bring his text up to date only as far as the end of 1957. Later advances were taken into consideration by the translator who added a number of footnotes; that is not a very satisfactory method. Roughly speaking, advances up to the end of 1959 have been embodied, but not consistently so. For instance, it is repeatedly said that the pion does not transform itself into an electron and a neutrino, although that transformation was discovered in 1958. Similarly it is stated that the neutral xi particle has not been found although it was observed in 1959. The properties of tau mesons are discussed at great length in the style of 1956, and it is not made clear that the discussion of all those elaborate hypotheses—trying to explain away the apparent violation of parity conservation—is now merely of historical interest.

However, there is a great deal to be learnt from this book which is by no means a mere review. The author is obviously an active and original worker in this field, and some of his remarks go beyond straight physics into questions of scientific strategy and philosophy. The style (although the German translation in places is clumsy) reflects in an attractive way the wide knowledge, and indeed the wisdom, of the author. But this is not a book for laymen. Full familiarity with operators and similar concepts of quantum theory is assumed throughout. Experimental methods are only lightly discussed. The lectures were obviously given to an audience of physicists who knew the subject in general but wanted to learn the details and to hear about trends and speculations. There is a good discussion of the current evidence for further particles, only one of which—tentatively called the D-meson—has since found further support. Much space is devoted to the various attempts to construct models of strange particles, such as Goldhaber's attractive idea of 'dions'.

There is also a good chapter on the hyper-fragments, discovered in about 1946 in Poland, *i.e.* nuclei which, having swallowed a hyperon, quickly die of explosive indigestion. Finally, there is a set of tables giving the computed energy thresholds for a large variety of reactions in which various particles are formed; this will be very useful to experimenters in planning their work. In the bibliography 248 items (nearly all pre-1958) bear eloquent witness to the great amount of work on this fascinating subject of 'strange particles'.

O. R. FRISCH,
Jacksonian Professor of Natural
Philosophy, University of Cambridge.

Nuclear Reactor Stability. By A. Hitchcock. Temple Press, London, 1960. Pp. 61. 12s. 6d.

Infinitesimal time intervals are usually required for nuclear reactions and upon this fact depends largely the efficacy of nuclear weapons. But for this feature, also, reactors would be more easily controlled, though less responsive to demands for power. Again, but for the fraction of delayed neutrons among the fission particles, control of reactors would be much more difficult than it is. But a fission reactor is still something needing careful handling, and the behaviour of reactor systems must be studied intently if safety in operation is to be achieved. On the one hand there is the physics of the static reactor; on the other hand is the kinetics of the reactor in a state of decreasing or increasing power. Between these two extremes lies a no-man's land of reactor instability. This is a no-man's land which must be studied, since it is only in this way that one can predict whether power in the system will remain reasonably steady during operations in the course of which inevitable small disturbances will arise.

It is a sight of this no-man's land, that of reactor stability, that Dr. Hitchcock has given us; and it is a picture which is carefully and lucidly presented. He considers a series of equations representing dynamic behaviour, and the physical conditions for stability, dealing with effects of uranium temperature, moderator temperature, xenon poisoning, steam voids, boiling-water reactors, delayed neutrons and neutron leakage. Instabilities due to temperature coefficients of reactivity are dealt with in greater detail, as are also instability due to voidage and that arising from xenon accumulation. Throughout the monograph, the systems envisaged are those having liquid or solid moderators, or boiling systems. This book is excellent, and is to be recommended for a clear treatment of the whole problem of reactor stability.

F. R. PAULSEN

Nuclear Notes

Ispra research centre

The European Atomic Energy Community (Euratom) now has at its disposal its first research centre. With the ratification by the Italian Parliament of the agreement concluded between Euratom and the Italian Government, the large-scale Ispra nuclear research centre has now been transferred to Euratom.

Ispra is one of the four branch establishments of the joint research centre which Euratom is setting up. The others will be at Petten (Netherlands), the transuranic elements institute at Karlsruhe (Germany) and the central nuclear measurements bureau at Mol (Belgium).

The research programme set up by Euratom is designed to put nuclear electricity production on a competitive footing and to extend the application of nuclear energy to other fields. The Ispra centre will thus be carrying out work on nuclear chemistry, nuclear physics, development and experimental work on novel types of reactor, etc.

Document guide

The U.K.A.E.A. has published a revised edition of its 'Guide to U.K.A.E.A. Documents'.

This explains to the public how the Authority publish information about their research, development, design and other work and where new publications are announced; how the Authority is organised into various autonomous groups, and by which of their establishments information is published; and where the public can obtain free access to read the publications—at depository libraries in Great Britain and 36 foreign and Commonwealth countries—or where they can buy them. A good deal of background information about various series of technical reports, from the early days of the Ministry of Supply, is also given for the many libraries with collections of them.

Among the new features of this edition are details of a sales service of scientific and technical reports, operated by the Authority, whereby the public may place standing orders for those on particular subjects; a further sales service operated by a Wakefield firm under contract, which provides micro-copies of older or out-of-print reports; and a list of bibliographies of atomic energy literature, compiled by the groups' libraries, available to the public.

Canada's export to Japan

Canada's first private export sale of nuclear fuel elements will be made to the Japan Atomic Energy Research Institute by A.M.F. Atomics Canada Ltd.

The contract is for 270 natural uranium fuel elements for use in the JRR-3 research reactor, a 10-MW heavy water-moderated research reactor operated by J.A.E.R.I., a Japanese Government agency.

Seven-inch-high core

An experimental nuclear core designed for use in a compact reactor which would generate electricity directly without moving parts has been tested successfully. The core is 7 in. high, 7 in. diam. $\frac{1}{8}$ cu. ft. in volume and weighs less than 200 lb.

It was designed and constructed for the U.S. Atomic Energy Commission's Office for Aircraft Reactors by Atomics International as part of a Commission programme to develop systems for nuclear auxiliary power for space vehicles.

The fuel and moderator in the core are a homogeneous mixture of uranium-235 and zirconium hydride. The heat conduction and reflector units are made of beryllium. The device is divided into two identical units which were brought together by remote control to achieve a sustained chain reaction. Each half was built up with alternate layers of fuel-moderator discs and circular conduction plates within a reflector.

MEETING IN VIENNA

The newly constituted board of governors of the International Atomic Energy Agency meeting for the first time in Vienna at the beginning of October.

Mr. Allan D. McKnight of Australia was unanimously elected chairman by the governors from 23 of I.A.E.A.'s member states serving on the board.

Five new members—Argentina, El Salvador, the Federal Republic of Germany, Iraq and Thailand—had been elected by the General Conference to succeed countries whose terms on the board had expired.

Full power at Dresden

The largest all-nuclear power plant in the U.S.A. at Dresden, Illinois, has reached full power.

The power station was built by U.S. General Electric for Commonwealth Edison, a leading American electricity supply company, and Nuclear Power Group Inc. It is the first full-scale, privately financed, nuclear power station to be built in the U.S.A. The 180,000-kW power station has a boiling-water reactor designed and built by General Electric.

Italian nuclear tanker

Representatives of the Comitato Nazionale per le Ricerche Nucleari, the Fiat Co. and the Ansaldo Ship-

yards have submitted to the Euratom Commission a study, research and development programme for a nuclear-powered ship.

This programme provides for the setting up of a project for a large tanker (52,000 tons), equipped with a water-type reactor of advanced design, to be developed in Italy. It is expected that Euratom will provide technical and financial aid for the execution of this programme, which will take two years and will be of potential interest to the nuclear industries of all the Euratom countries.

Harwell library

A new building housing the main library and the document reproduction section at Harwell was opened recently by Sir Lindor Brown, C.B.E., chairman of the Consultative Committee of the National Lending Library for Science and Technology of D.S.I.R.

The building has a total floor area of 40,000 sq. ft. and the cost is about £200,000.

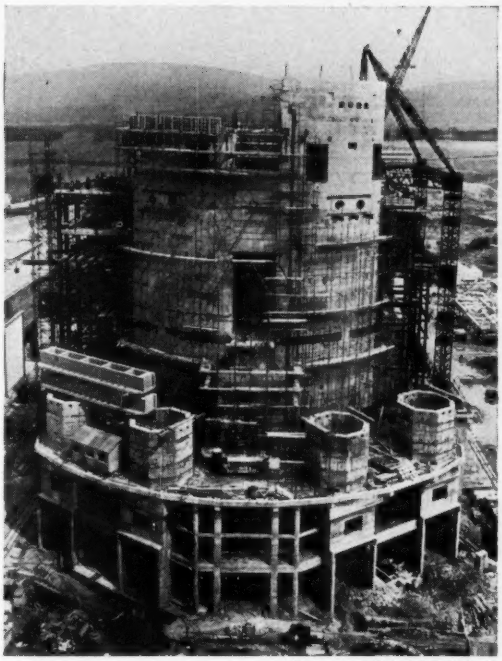
The library has a stock of some 20,000 volumes of books and periodicals, 250,000 copies of technical reports, 50,000 micro-cards and 27,000 pamphlets, and includes the largest collection of atomic energy literature in the country. Expansion in this field is exceptionally fast, about 4,000 volumes and 30,000 copies (13,000 titles) of reports being added annually, but coupled with a vigorous weeding programme it is hoped that provision has been made for 15 years' growth.

Reference and loan services are provided, not only to Authority staff at Harwell, but also to staff attached from various organisations at home and abroad, and to staff and visitors at the Rutherford high-energy laboratory of the National Institute for Research in Nuclear Science. To meet these requirements there must be completely free access to the reading room and book stack, but restricted access to other parts of the building; this has presented novel planning problems but, with the use of a site on the perimeter of the establishment, solutions have been found.

Graaff accelerator for Swedish research

A van de Graaff accelerator, weighing 70 tons and designed for a maximum voltage of 5.5 million V., has been installed at the Swedish Atomic Energy Co.'s research station, Studsvik, on the Baltic coast south of Stockholm. The American-manufactured unit has cost about Kr. 2.5 million ($500,000).

A view of the plinth of the steam-raising units of the reactor B at Hunterston Nuclear Generating Station. Two of the concrete beams which will form part of the soffit of the roof biological shield are shown ready for lifting into position.



(Courtesy of the G.E.C. Ltd.)

The accelerator, housed in a nitrogen-filled pressure tank and installed in a 24-m. (80-ft.) tower, is primarily intended for gauging neutron physical data needed in connection with calculations for fast reactors and irradiation protection. In the unit the accelerated ions reach a speed of one-fifteenth of the speed of light and are made to bombard different materials, such as lithium or tritium. The energy of the neutrons released through this nuclear reaction can be varied with great accuracy within the span of 0.2 to 22 MeV.

Nuclear Liability Convention

The O.E.E.C. Council has concluded its examination of the International Convention on Third Party Liability in the Field of Nuclear Energy.

The Convention, to which is attached an Exposé des Motifs, represents the conclusion of the work of the European Nuclear Energy Agency to elaborate a uniform European régime that takes account of the technical, economic and financial conditions of the nuclear industry, and provides rules for compensation in case of claims resulting from nuclear incidents. The Convention covers accidents which occur at nuclear installations and those arising in the course of transport of radioactive substances.

The Convention will come into force when it has been ratified by five signatories; with nuclear third party liability legislation pending in a number of European countries it is expected that some early ratifications will be received.

Radiation dose in bone

Present knowledge about the relationship between radiation dose in bone and the damage it causes is reviewed in a brief publication recently issued by the International Atomic Energy Agency. It is a report of a small conference on the relation of radiation damage to radiation dose in bone which was held in Oxford, earlier this year, with the support of the Agency and the U.K. Medical Research Council.

The report begins with a discussion on the techniques for the measurement of radiation dose in bone. It is pointed out that the study of the relationship between the dose and the damage caused depends on adequate techniques for dose measurement.

The next section is devoted to an analysis of the relationship of the dose with tissue damage and the production of bone tumours. Bone damage takes two forms. Firstly the bone cells may be killed and, secondly, the radiation can initiate abnormal activity in the growing bone tissue. This can eventually be followed by the growth of malignant tumours. The relationship between tissue damage and the development of bone tumours was discussed.

CORRESPONDENCE

Graphite for Chemical Plant

SIR,

I noted in the article on 'Graphite as a Material of Construction for Chemical Plant' which appeared in the September issue of CHEMICAL & PROCESS ENGINEERING, certain statements concerning the *Polybloc* system of construction (called by the authors 'composite ring type') which require correction. They suggest on page 413 that the passages are small (meaning, presumably, of small diameter) and subject to blockage. It should be obvious that any passage diameter, within the limits of the size of block, can be used in the system. An example is Fig. 4 on page 418, which illustrates a *Polybloc* element with axial passages of 1-in. diam., fluting out to 1½ in.

The suggestion that the system imposes necessarily small-diameter passages is as irrelevant as that of blockage. As graphite normally forms no solid compounds, the authors presumably mean by blockage, the fouling of passages by precipitates or other solid constituents of a heat-exchange fluid, which are held by surface conditions, *e.g.* in the streamline layer associated with laminar flow through long tubes.

The pertinent factor is the ratio of length to diameter of the passages. In the *Polybloc* system, all passages are very short with respect to their diameter, which induces turbulent flow, and inhibits fouling. The same mechanism which produces the very high heat-exchange coefficients is also responsible for the anti-fouling effect which characterises the *Polybloc* system.

Concerning the authors' suggestion that bulkiness is the only shortcoming of tubular heat exchangers, I would refer to page 416 of my article in your journal. The tubular system was developed for metallic (isotropic) materials of construction, for which it is eminently suited. It is difficult to understand why it was ever applied to graphite, which is highly anisotropic. Table 2 on page 410 indicates the poor tensile and flexural strength of graphite and shows that its good mechanical property is compressive strength. In the tubular system graphite is used in the form of long, thin shapes (tubes) and subjected to tensile and flexural stresses, and no use is made of the good compressive strength. Any preferred orientation of graphite crystals is in tubes conducive to lower thermal conductivity in the direction of the desired heat transfer (see page 410). The large length/diameter passage ratio which characterises tubular units favours streamline fluid flow, lower heat-exchange coefficients and increased fouling tendency.

Cemented joints are required to fix the tubes in the header plates (page 412). Whereas the authors mention resin cements which almost match the chemical resistance of carbon itself, it is recalled that, under the effect of time, temperature, chemical reagents, etc., cements tend to age, become brittle and may loose their homogeneity. Most chemical plant, and particularly heat exchangers, are subjected to conditions of temperature changes, which introduces the risk of disintegration of embrittled, or otherwise aged, cemented joints through differential expansion. A multiplicity of requirements limits the choice of materials, and I do not know of any resin which, after setting and ageing, satisfies the added requirement of having an expansion coefficient identical with that of the carbon.

It is possible that, because of their fragility, graphite tubes may fail through mechanical breakage before deterioration of cemented joints becomes apparent. I doubt whether such joints can remain permanently fluid tight under conditions encountered in the majority of heat-exchange problems.

The detachable gaskets of the *Polybloc* system avoid these shortcomings and permit the use of jointing materials (PTFE, etc.) which have comparable inertness to that of carbon. These and other considerations raise the question whether there exists a constructional method which is less suitable, or employs graphite to worse advantage than does the tubular system.

The authors' suggestion that the ultimate type of construction is in very large, drilled, single blocks raises a number of practical problems. Accurate drilling of holes becomes increasingly difficult with increasing length/diameter ratio, particularly because, for reasons of economics, high-speed and multi-spindle drilling is required. Even if the important aspect of economics is disregarded, and long drilled holes were envisaged, they would introduce the problem of streamline fluid flow, with corresponding tendency for lower heat-exchange efficiency and fouling.

I agree with the authors that the exceptional properties of carbon merit its increasing use as a constructional material. However, to do it justice, it must be employed in a way which suits its characteristics. It is essential to appreciate that in the form of graphite its properties are fundamentally different from those of any other constructional material. To superimpose it on constructional systems which were designed for materials of basically different properties, *e.g.* metals, cannot be right.

A. HILLIARD.

Technical adviser,
Société le Carbone-Lorraine,
62 Finsbury Pavement,
London, E.C.2.

(We passed Mr. Hilliard's comments to the authors of the article who replied as follows—EDITOR)

SIR,

As authors of this article we would like to point out in reply to Mr. Hilliard's contentions that we had no wish to take sides on the relative merits of various types of graphite heat exchangers and merely attempted to indicate the 'possible' advantages and disadvantages of the types mentioned. We do not believe that perfection has been achieved with any of these designs, and the commercial and technical considerations for and against each type can be argued at great length. We have no desire to elaborate upon these considerations.

We agree with Mr. Hilliard that carbon plant is best designed to operate under compressive stresses, and we acknowledge the care taken in the design of the *Polybloc* heat exchanger to make best use of the material and obtain favourable heat-transfer conditions. We also agree that the methods taken to create turbulent conditions inside the heat exchanger are likely to be non-conducive to the formation of surface

scale. We do still feel, however, that in some of the very dirty conditions which we have met, where perhaps the filtration systems have not been all that might be desired, the use of small flow passages could cause serious blockage regardless of the degree of turbulence which is present. According to information available to us the 'standard' *Polybloc* unit incorporates passages of 0.315 in. diam. both axially and radially.

The possible use of larger holes in the same type of construction seems to us to lessen to some extent one of its great attractions. The use of smaller-diameter holes does ensure that a larger heat-exchange surface area can be compacted into a small volume.

With regard to the use of cemented joints we must say that we have had experience with tube bundles incorporating cemented joints and these have caused no difficulty. By developing cements composed of mixed resins we have been able to obtain chemical resistance almost equal to carbon itself, and we have not met with any problem of ageing joints or failure of joints. We feel that many users of graphite heat exchangers of the tube bundle type could confirm that the inability to match the coefficient of expansion of resin cements with that of carbon is no problem in practice.

With regard to Mr. Hilliard's comment concerning the use of tubes having the poorest thermal conductivity in the direction of heat transfer, we do not consider that this is too serious a factor for most heat-exchange applications. Only under film evaporation conditions perhaps does the conductivity play an important part in the overall transfer. The degree of crystal orientation obtained in graphite tubes can be reduced to quite a low level by careful selection of material and attention to processing methods.

In conclusion we would state that Mr. Hilliard in his letter has emphasised the importance of the correct use of carbon in the design of plant and with this we entirely concur. We feel, in general, that the properties of graphite make it an ideal material for use in the construction of heat exchangers and that the selection of the type of unit to use must depend upon the actual application and the conditions.

K. F. Anderson
F. K. Earp
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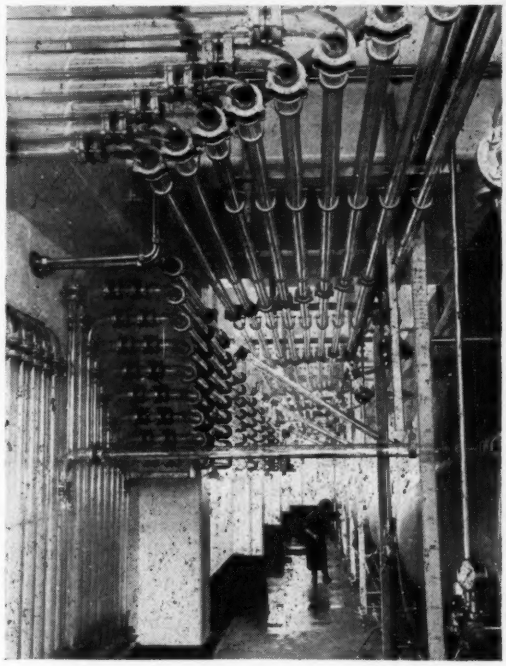
London, S.W.11.

CPE Company News



Part of an installation consisting of over a mile of 2-in.-bore glass pipeline, recently installed at Flower and Sons' brewery at Stratford on Avon by Q.V.F. Ltd.

Beer installation

About 50 bbl./hr. of beer can pass through any main in an installation consisting of over a mile of glass pipeline recently installed by Q.V.F. Ltd. in a new tank-storage building at the Stratford on Avon brewery of Flower & Sons Ltd.

The new tank-storage building has provided an additional capacity of 57,600 gal. Two-in.-bore glass pipeline is used because it is more economic than stainless steel or copper, easy to clean and ideal for observation purposes.

Tanks are pressure vessels capable of working to 30 p.s.i. Beer is subsequently piped from the bottom of the storage tank to the chiller inlet. It passes through one of two plate heat exchangers, which reduces its temperature to 32°F. From the chillers the beer is piped back to the original tank. The chilling system is, in effect, an automatically controlled closed circuit.

Reforming plant in Guernsey

Simon-Carves Ltd. have recently commissioned an *Otto* continuous catalytic reforming plant for the Guernsey Gas Light Co. to produce town gas from commercial butane. The plant produces all the gas for the island.

Thermal efficiencies in excess of guarantees are obtained, and the gas is sulphur-free.

There are two completely independent plants, one of which is normally in operation to meet the whole of daily requirements.

This is the first plant of its type to be installed in the U.K., though there are some 28 in operation on the Continent.

Liquid helium plant

Britain's first liquid helium plant started service recently at the Morden works of British Oxygen Research & Development Ltd. The plant will produce sufficient liquid helium to meet all present demands from industry and research bodies in this country.

The National Physical Laboratory, Teddington, which has run a plant for a number of years, is now gradually discontinuing production and handing over its customers to the company. The only other sources of liquid helium in the U.K. are certain university laboratories where low-temperature research is carried out.

Orders and Contracts

Ammonia plant

A contract for a multi-million-dollar ammonia plant which will feature an ammonia synthesis converter with the largest single designed capacity in the world has been awarded to Chemical Construction Corporation. The plant is being designed and constructed by Chemico for U.S. Phosphoric Products in Tampa, Florida.

The plant will use natural gas as a raw material and will have a capacity of 350 tons/day.

Turbo driers

Buell Ltd. a subsidiary of Edgar Allen & Co. Ltd., have received an order for the erection of three vertical turbo driers, each with an output of 9½ tons/hr. of china clay. The three driers will be installed at three different sites in the Cornish area, and the erection of the first is due to begin in November of this year and be in operation by next March. The total value of the order is about £100,000.

Nuclear instrumentation

Plessey Nucleonics Ltd. have received an order from the U.K. Atomic Energy Authority for the supply of all the nuclear instrumentation for the Authority's advanced gas-cooled reactor at Windscale.

The complete instrumentation assembly—consisting mainly of standard instruments currently in production—will incorporate all the equipment necessary for complete reactor control and safety during start-up, normal running and shut-down conditions.

Coking plants

Woodall-Duckham Construction Co. Ltd. has received orders to build two new coking plants together valued at over £4 million.

One of the orders is from Colvilles Ltd., who have ordered two further batteries of coke ovens with complete coal- and coke-handling systems and a by-products recovery plant for their Ravenscraig works. This new plant will have a coke output capacity equal to that of the plant at present under construction, so that by the end of 1962 when all six batteries will be in operation the Ravenscraig works will be processing 1¾ million tons of coal annually.

The other plant is for the United Coke & Chemicals Co. Ltd. at Orgreave. The contract includes the demolition of a derelict battery of ovens and the building of a new battery of 43 ovens with by-products recovery and benzole plants and a gas boosting plant. Demolition work is already in progress and the building of the new installation will be completed by the end of 1962.

Super critical generating units

The Central Electricity Generating Board have placed contracts valued at about £15 million for two large, supercritical pressure generating units to be installed at Drakelow C power station, near Burton-on-Trent. One boiler will be built by Babcock & Wilcox Ltd. and the other by International Combustion Ltd., and the turbo-alternators by A.E.I. Ltd. and the English Electric Co. Ltd., respectively. Each generating unit will have an output of 375,000 kW from a single-shaft machine.

Steam conditions for both machines are 3,500 p.s.i. at the turbine stop valve and 1,100°F. The steam, after partial expansion, will pass through the boiler again and will be reheated to 1,050°F. before re-entering the turbine for expansion to vacuum.

Reactor control study

The Babcock & Wilcox Co. has been awarded a contract worth over $1 million by the U.S. Atomic Energy Commission for the study of the physics aspects of a new method of nuclear reactor control originated by the company.

Called the 'spectral shift' method of control, it will use a mixture of heavy and light water to act both as a reactor system coolant and as a moderator to control pressurised water reactors. Its use is expected to increase the life of water reactor cores, increase the efficiency of fuel consumption, and replace portions of the costly and intricate control rod systems now in use.

£ s d

CHEMICAL PLANT COSTS

Cost indices for the month of September 1960 are as follows:

Plant Construction Index: 181.1

Equipment Cost Index: 169.7

(June 1949 = 100)

£ s d

Polyolefine film production

A joint company is being formed by Shell International Chemical Co. Ltd., London, and National Distillers & Chemical Corporation, New York, to develop plans for the production and marketing of polyolefine film and plastic packaging materials outside the U.S.A. and Canada.

The new joint company, which will operate from London, will be headed by Dr. W. L. J. De Nie, at present a senior executive of Shell Development Co., New York.

New refinery

Kellogg International Corporation (London) has been awarded a contract to engineer and build a new refinery for Pakistan Refinery Ltd., near Karachi, Pakistan. Participating in Pakistan Refinery Ltd. are the Burmah Oil Co., Caltex, Shell and Stanvac, together with Pakistani interests. Bataafse Internationale Petroleum Maatschappij are the technical co-ordinators for this project.

The refinery will consist of a 34,000-bbl./day crude distillation unit, a catalytic reforming unit and a hydro-treater. Offsites include a marine terminal and a crude oil pipeline from the port to the refinery site.

Dismantling an ironworks

A contract has been awarded to George Cohen Sons & Co. Ltd. for the dismantling and disposal of the plant and buildings of the former Normanby ironworks in Middlesbrough.

The task of dismantling the three blast furnaces, continuous pig plant, chimneys, gas washers and other plant amounting to almost 9,000 tons has already begun and it is expected that work will be completed within 12 months.

Scottish works reconstruction

Scottish Agricultural Industries Ltd. are planning reconstruction of their Sandilands chemical works, Aberdeen, at a cost of over £1 million. The company took over this factory in 1928, and will start work on the scheme this year, completing it by the summer of 1962. At present, the plant produces superphosphate-based fertilisers, but after reconstruction manufacture of complete fertilisers will be undertaken. Policy will be to maintain full production during the period of modernisation.

CPE World News

NETHERLANDS

Synthetic rubber

A new synthetic rubber plant costing over £10 million and initially capable of producing 60,000 tons p.a., was opened recently at the Shell Pernis refinery near Rotterdam.

The plant covers 25 acres. It will be able to supply all the synthetic rubber of the styrene/butadiene type that the Benelux countries need. Large quantities will also be exported. The plant consists of three units—one for the manufacture of styrene, one for the production of butadiene and a polymer plant where the two raw materials are combined to produce synthetic rubber.

Phenol factory

A phenol plant to be built at the Botlek area in Rotterdam will be jointly owned by Staatsmijnen in Limburg and Dow Chemie A.G., the Swiss subsidiary of the Dow Chemical Co. The cost of the project is estimated at 40 million Dutch guilders (over £3.5 million).

An important portion of the production will be used for the phenol requirements of Staatsminjen in Limburg. The rest of the production capacity will be marked by Dow Chemical International Ltd. S.A.

INDIA

Gelatine manufacture

A new company, Leiner-Knot Gelatine Co. Ltd., is to set up a factory which will produce 2,000 tons p.a. of edible, pharmaceutical and technical gelatines and also bone glues using sinews for the raw material.

The site of the factory has not been chosen yet, but production is planned to start in about six to nine months' time. One of the main products will be gelatine for banknote paper to be made in the new mill being built by the Indian Government in conjunction with Portals Ltd. The majority of bone glue produced will go to the U.K.

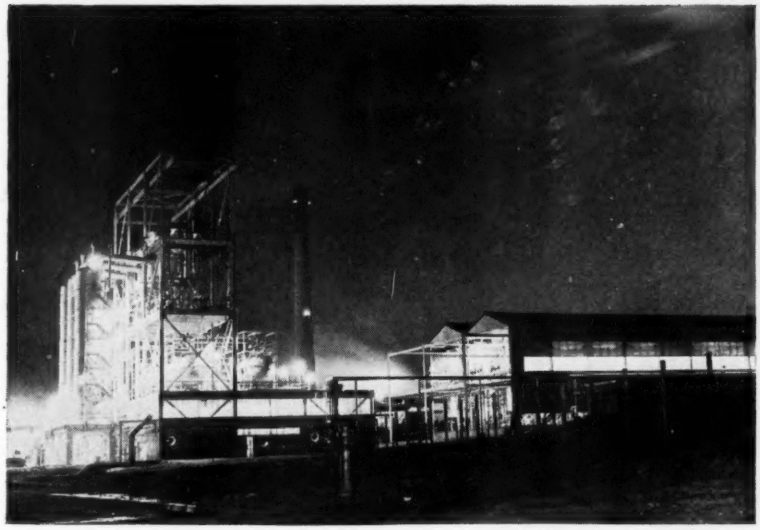
SPAIN

Petroleum complex

An agreement has been reached between Dow Chemical Co. and Union Quimica del Norte de Espana S.A. (Unquinesa) to construct a petrochemical complex in Spain.

The basis of the agreement is Dow's financial and technical participation in the development of a petrochemical industry in Spain. An approval for the joint venture already has been secured from the Spanish government.

The development plan includes the construction of a cracking unit which will produce ethylene and propylene. The resulting C4 fraction will be further processed to recover butadiene. Effluent gas will be used in Unquinesa's existing methanol plant, substituting for gasified carbon materials.



A night view of the site of the International Rubber Co. Ltd. at Hythe, Southampton, where the first large-scale plant in the U.K. for the production of high solids styrene butadiene rubber latex is now operating.

GREECE

Sulphuric acid plant

A contract for the largest single-unit sulphuric acid plant in Greece has been awarded to Chemical Construction (G.B.) Ltd. This will be a 376-metric-ton/day sulphur-burning sulphuric acid plant. Chemico will furnish the design, engineering, equipment and supervision of construction and initial operation of this plant.

The plant will be at Ptolemais, in northern Greece, and erected for the Greek Ministries of Industry and Coordination as a part of a large nitrogenous fertiliser factory.

NORWAY

Chemical factories

It is now considered fairly certain that the Norwegian Government will approve the construction of a coking plant at Mo i Rana. The annual capacity of the plant will be 230,000 tons of coke and the production will be based on coal supplies from Spetsbergen (Svalbard). The construction costs are estimated at 75 million kroner (£3,750,000). In connection with the erection of the plant, some factories for chemical products will also be constructed. There are plans for erecting a factory for ammonia which will make use of the gas from the coking plant, a sulphuric acid factory and a factory for the production of ammonium sulphate.

The ammonia and sulphuric acid factories will supply their products to the ammonia sulphate factory, the annual capacity of which has been estimated at 200,000 tons of ammonium sulphate. The construction costs of the three plants are calculated to be 140 million kroner (£7 million). The coking plant will be erected by the government and the three chemical plants will be erected by a private company, Norkemi A/S.

CPE Diary

NOVEMBER 8 TO 10 Conference on **non-destructive testing in electrical engineering.** Details from the organisers, the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

NOVEMBER 14 TO 18 Symposium on **nuclear ship propulsion with special reference to safety** to be held in Italy. Organised by the International Atomic Energy Agency and the Intergovernmental Maritime Consultative Organisation. Details from I.A.E.A., 11 Kartner Ring, Vienna 1, Austria.

NOVEMBER 17 Meeting on the **control of a single-effect concentrating evaporator** dynamic characteristics and analogue computer study, to be held at Manson House, 26 Portland Place, London, W.1, at 6.30. Details from the organisers, the Society of Instrument Technology, 20 Queen Anne Street, London, W.1.

NOVEMBER 21 TO 23 Seminar on **analogue computation applied to the study of chemical processes** organised by Institut Belge de Regulation et D'Automatisme to be held in Brussels. Details from R. Vichnevetsky, c/o Centre European de Calcul Electronics Associates Inc., 43 rue de la Science, Brussels 4, Belgium.

NOVEMBER 21 TO DECEMBER 16 General **isotope course** at the Isotope School, Wantage Radiation Laboratories, Wantage, Berks. Organised by the U.K.A.E.A. Details from the school.

NOVEMBER 25 TO 26 Meeting of the **American Physical Society** in Chicago. Details from the Society, Pupin Physical Laboratory, Columbia University, New York 27, N.Y., U.S.A.

NOVEMBER 26 Annual **dinner and dance of the Institution of Plant Engineers,** London branch, at the Waldorf Hotel. Details from the Institution of Plant Engineers, 2 Grosvenor Gardens, London, S.W.1.

NOVEMBER 28 TO DECEMBER 2 Symposium on **experimental and test reactors** in Vienna. Information from the organisers, I.A.E.A., 11 Kartner Ring, Vienna 1, Austria.

NOVEMBER 29 Symposium on **nuclear temperature scanning** at 26 Portland Place, London, W.1, at 6.30. Details from the Society of Instrument Technology, 20 Queen Anne Street, London, W.1.

NOVEMBER 29 TO DECEMBER 2 **The Corrosion and Metal Finishing Exhibition** to be held at Olympia. Organised by Leonard Hill Ltd. Details from the Director, the Corrosion and Metal Finishing Exhibition, 9 Eden Street, London, N.W.1.

NOVEMBER 30 TO DECEMBER 2 Second **Reinforced Plastics** Conference at the Cafe Royal, London. Information from the British Plastics Federation, 47-48 Piccadilly, London, W.1.

DECEMBER 6 Lecture on the study on **electro-precipitator performance in relation to particle size distribution, level of collection efficiency and power input,** by D. O. Heinrich, at the Geological Society, Burington House. Details from the Institution of Chemical Engineers.

DECEMBER 12 TO 14 Winter meeting of the American Nuclear Society, including conference on **hot laboratories and equipment and the Atomic Industry Exhibition,** in San Francisco, California, U.S.A. Organised by the American Nuclear Society. Details from the secretary of the society, Mr. O. du Temple, c/o John Crerar Library, 86 East Randolph Street, Chicago 1, Illinois, U.S.A.

DECEMBER 14 TO 16 Annual conference of the **Atomic Industrial Forum.** Information from the forum, 3 East 54th Street, New York, 22.

New method of transport

Start of a journey by the Portolite flexible container of iso-octanol. The interior lining of the tank is of rayon-reinforced butyl rubber which is inert to iso-octanol.

I.C.I. heavy organic chemicals division have used a flexible *Portolite* tank to transport a consignment of one of their petroleum chemical products by road. A round trip of several hundred miles was made when 2,000 gal. (over 7 tons) of iso-octanol were carried to a U.K. customer from the division's works at Billingham, Co. Durham.

The *Portolite* tank was filled on the deck of the flat-bottomed lorry in a normal manner and was then lashed down with ropes; no built-up sides were required. When full, the container measured some 15 ft. in length and 8 ft. in width, with a height of 2 ft. 6 in. However, for the return journey it was possible to roll the empty container to take up only about 3 ft. of the lorry's deck, leaving 12 ft. free for other purposes and effecting considerable economies in transport costs.